Open Tibia Fracture Management in Lesser-Resourced Settings: Latin America

M.C. MacKechnie

Open Tibia Fracture Management in Lesser-Resourced Settings: Latin America

M.C. MacKechnie

Open Tibia Fracture Management in Lesser-Resourced Settings:
Latin America

Behandeling van open tibiafracturen in gebieden met minder middelen:
Latijns Amerika

Madeline Camilla MacKechnie

Open Tibia Fracture Management in Lesser-Resourced Settings:
Latin America

Behandeling van open tibiafracturen in gebieden met minder middelen:
Latijns Amerika

Thesis

to obtain the degree of Doctor from the
Erasmus University Rotterdam
by command of the
rector magnificus

Prof.dr. A.L. Bredenoord

and in accordance with the decision of the Doctorate Board.
The public defence shall be held on

Thursday, 30 November 2023 at 10.30 hours

by

Madeline Camilla MacKechnie

Born in Seattle, WA, United States of America

Erasmus University Rotterdam

Doctoral Committee

Promotors:	Prof.dr. M.H.J. Verhofstad Prof.dr. T. Miclau III
Other members:	Prof.dr. A. Burdorf Prof.dr. J.M. Hendriks Prof.dr. J. Dankelman
Copromotor:	Dr. E.M.M. Van Lieshout

Table of Contents

PART I. CLINICAL RESEARCH: REGIONAL BARRIERS 8

Chapter 1. General Introduction and Outline of Thesis 10
Chapter 2. Barriers to Clinical Research in Latin America 20
Chapter 3. Asociación de Cirujanos Traumatólogos de las Américas [Association of Trauma Surgeons in the Americas]: Development of a Latin American Research Consortium 31
Chapter 4. Leadership Development for Orthopaedic Trauma Surgeons in Latin America: Opportunities for and Barriers to Skill Acquisition 41
Chapter 5. Building Leadership Development Capacity for Orthopaedic Surgeons in Latin America 58

PART II. CLINICAL RESEARCH: REGIONAL PRIORITIES 69

Chapter 6. Establishing Consensus on Essential Resources for Orthopaedic Trauma Care Worldwide: A Modified Delphi Study 71
Chapter 7. Orthopaedic Trauma Research Priorities in Latin America: Developing Consensus through a Modified Delphi Approach 91

PART III. OPEN TIBIAL SHAFT FRACTURES: CURRENT MANAGEMENT 106

Chapter 8. Open Tibial Shaft Fractures: Treatment Patterns in Latin America 108
Chapter 9. Management of Soft-Tissue Coverage of Open Tibia Fractures in Latin America: Techniques, Timing, and Resources 131
Chapter 10. Predictors of Clinical Outcomes for Open Tibia Fracture Management Across Latin America: A Prospective Multi-National Study 149

PART IV. OPEN TIBIAL SHAFT FRACTURES: INTERVENTIONS 174

Chapter 11. Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An Analysis of Participants in an Orthopaedic Surgical Skills Training Course in México 177
Chapter 12. Open Tibial Shaft Fracture Management in Argentina: An Evaluation of Treatment Standards in Diverse Resource Settings 191
Chapter 13. General Discussion and Future Directions 209
Chapter 14. Summary and Summary in Dutch 219

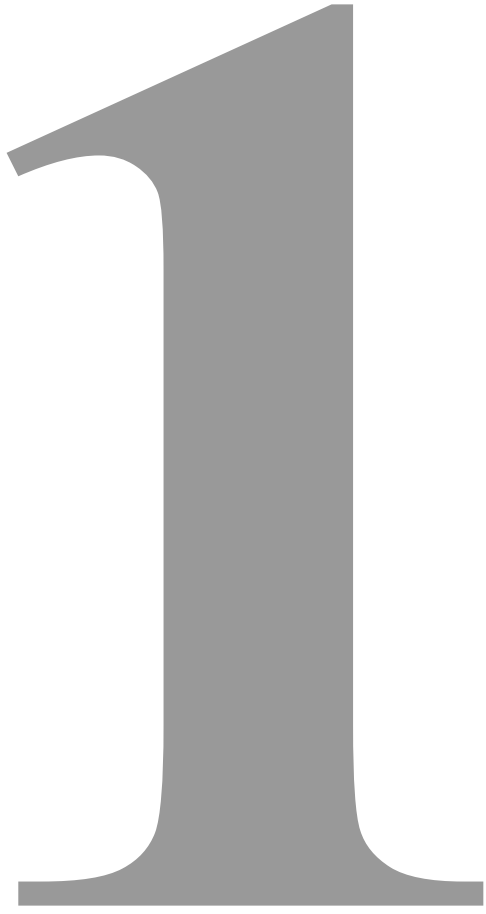
APPENDICES 233

List of Publications 235
Contributing Authors 239
PhD Portfolio 245
Acknowledgements 249
Curriculum Vitae 251

PART I

Clinical Research: Regional Barriers

CHAPTER 1



General Introduction and Outline of Thesis

Introduction

Injuries are increasingly recognized as a major contributor to the Global Burden of Disease, with over four million deaths caused annually, totaling more fatalities than those from HIV/AIDS, tuberculosis, and malaria combined.[1] Musculoskeletal conditions comprise a large subset of this burden, with an additional 20-50 million injured from road traffic incidents causing lifelong disability.[2] For these patients, the loss of limb function can severely limit their productivity, posing challenges for the individual, family, and society.[3] While orthopaedic conditions account for the greatest proportion of chronic pain across income levels and age,[4] those in low-and middle-income countries (LMICs) are disproportionately affected.[5]

Latin America, a region comprising predominantly Spanish-speaking LMICs, has the highest per capita road traffic fatalities worldwide.[6] As a result, open fractures are a significantly problematic regional health issue, with a high rate of incidence, risk of complications, and associated poor long-term outcomes.[7] These fractures represent a surgical emergency associated with high morbidity, and management includes systemic antibiotic prophylaxis, wound debridement and coverage, and fracture stabilization.[8] Given the severity of these injuries, leading health agencies such as the World Health Organization (WHO) and Lancet Commission on Global Surgery, have designated open fractures as a "bellwether" essential surgical procedure.[9,10] This designation represents a recognition of both the critical importance of open tibia fractures as a significant injury and as an indicator for traumatic conditions. Despite the fact that expeditious treatment is considered a critical component of management for open tibia fractures, little is known about the current state of management of these injuries in Latin America or the prevalence of regional differences.[11,12]

Notably, musculoskeletal trauma literature originating from Latin America remains underrepresented in major orthopaedic journals,[13] and even among LMICs, this region was represented in only 3.1% of musculoskeletal trauma studies worldwide.[12] Moreover, orthopaedic surgery has been recognized as having the fewest collaborative multi-center publications relative to other specialties.[14] Lack of investigational infrastructure and knowledge, problematic patient follow-up and charting data, publication bias, and unfamiliarity with the English language have been cited as barriers to conducting research in this region.[15–17] The paucity of population-specific research evaluating the burden of trauma in general, and musculoskeletal injury in particular, limits the ability to address improvements in management of trauma-related conditions. Only through evidence-based research and collaborative investigational organizations can surgeons improve their skills and knowledge and address barriers to regional problems.[18]

Because treatment guidelines are often derived from higher-income countries (HICs), most frequently from North America and Europe, these recommendations are not always generalizable to countries in Latin America. Further, management outcomes are impacted by the lack of trauma care infrastructure, surgical training, rehabilitation systems, and preventive efforts in lesser-resourced environments.[1] Besides having fewer resources and less access to informed data on open tibia fractures, orthopaedic surgeons in Latin America face additional challenges to adequately manage the burden of injures, including the lack of formalized guidelines across countries, lack of training to provide soft-tissue reconstruction, and lack of expertise and specialists, as well as non-clinical factors including few "soft-skill" development opportunities in leadership, research, and organization. Thus, there is a significant need for not only better

understanding of open tibia fractures in Latin America, but also for non-clinical capacity-building skills for orthopaedic trauma surgeons needed to manage these injuries.[10]

Aim

The purpose of the thesis is to: 1) identify barriers relevant to clinical research in Latin America; 2) define clinical needs, clinically- and regionally-relevant research priorities, and explore the management of open tibia fractures across the region; and 3) address the treatment of open tibia fractures by developing best practice guidelines, taking into account the low-and-middle income countries' (LMICs) resource-limited settings in Latin America.

Outline of Thesis

The thesis begins with a general introduction and thesis outline in **Chapter 1**. This chapter provides a brief overview on the Global Burden of Disease for noncommunicable diseases and gives insight into contributing factors that have led to a rise in musculoskeletal injuries across low-and middle-income countries (LMICs), particularly as it relates to the high rates of open tibia fractures in Latin America. This introductory chapter describes the relative lack of orthopaedic trauma studies and subsequent publications originating from this region.

The first part of the thesis investigates the barriers to clinical research and non-clinical opportunities faced by orthopaedic trauma surgeons in Latin America. Recognizing the underrepresentation of Latin America in orthopaedic trauma-related studies, **Chapter 2** details the barriers faced by orthopaedic surgeons to participate in clinical research activities and provides a needs assessment on orthopaedic trauma surgeons to gauge ways to overcome this evidence gap. In response to the identified barriers and desires in chapter 2, **Chapter 3** describes the development of a novel consortium of Latin American orthopaedic trauma surgeons, the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR), which was created to address clinically-relevant research questions in the region, seeking to develop capacity through collaborative studies. **Chapter 4** assesses the orthopaedic trauma surgeons' needs and desires to develop non-clinical leadership development skills, which are also critical for leadership in research. Taking into account the surgeons' responses to the needs assessment in the previous chapter, **Chapter 5** describes the creation of the first Leadership Development Program (LDP) for orthopaedic trauma surgeons that was delivered in Hermosillo, Mexico at the second largest orthopaedic trauma conference in Latin America.

The second part of the thesis investigates regional resource and clinical research priorities, and begins with **Chapter 6**, which utilizes a modified Delphi study design to determine the most critical orthopaedic trauma care resources by an expert panel of orthopaedic surgeons from low-and middle-income countries (LMICs), upper-middle income countries (UMICs), and high-income countries (HICs). Using consensus opinion, this chapter highlights the resources considered "most essential" and regionally-relevant as a first step towards developing guidelines and creating best-practice treatment standards for surgeons in any given resource setting. Similarly, **Chapter 7** utilizes the modified Delphi study design to identify the most critical musculoskeletal clinical issues perceived by an expert group of Latin American orthopaedic surgeons.

The third part of the thesis focuses on current management techniques of open tibia fractures, beginning with **Chapter 8**, which provides insight on Latin American orthopaedic surgeons' open tibia treatment patterns; factors evaluated include antibiotic prophylaxis, irrigation and debridement, fracture stabilization, and wound management. Further, **Chapter 9** focuses more specifically on the management of soft-tissue wound coverage for open tibia fractures in this region. **Chapter 10** seeks to identify clinical outcomes associated with health-related quality of life scores at one-year for open tibia fracture management in Latin America. This multi-national, multi-center prospective observational study is the largest to date, with 16 Latin American trauma centers participating from seven countries across the region.

The fourth part of the thesis describes two interventions used for improving standardized treatment of open tibia fractures. **Chapter 11** highlights the effectiveness of a hands-on surgical skills course which can be used as a model to address gaps in care. Given the reported lack of soft-tissue reconstruction training by orthopaedic surgeons in Latin America, this chapter describes the development and efficacy of a surgical program, the Surgical Management and Reconstructive Training (SMART) Course, delivered in Mexico. This course instructs orthopaedic surgeons' techniques to treat the open tibia fracture and soft-tissue wound to prevent severe infections and amputations. This chapter shows the impact that such surgical training courses can have on orthopaedic surgeons' clinical skills and confidence levels when managing open tibia fractures. **Chapter 12** provides a case example describing the efforts of the Argentinian Association of Traumatology and Orthopaedics (AATO) to promote national standardization for the treatment of open tibia fractures across its country's diverse landscape. The results from this study illustrate that surgical education initiatives can be effective in improving and standardizing surgeons' treatment of open tibia fractures across diverse and lesser-resourced settings.

Finally, **Chapter 13** provides a general discussion of the most relevant outcomes from the thesis and addresses the impact the results can have on the future of orthopaedic management of open tibia fractures in Latin America and, more broadly, on the Global Burden of Disease. This chapter also addresses future directions, highlighting areas of further investigation that are needed in order to bridge the gap between the findings presented and implementation. **Chapter 14** summarizes the results presented in the thesis.

References

1. Gosselin RA, Spiegel DA, Coughlin RR, Zirkle LG. Injuries: The Neglected Burden in Developing Countries. *Bull World Health Orga*. 2009;87(4).
2. Mock CN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Clin Orthop Relat Res*. 2008;466(10):2306-2316.
3. O'Hara NN, Mugarura R, Slobogean GP, et al. The Orthopaedic Trauma Patient Experience: A Qualitative Case Study of Orthopaedic Trauma Patients in Uganda. *PLoS One*. 2014;(9):e110940.
4. Tsang A, Von Korff M, Lee S, Alonso J, Karam E, Angermeyer MC, et al. Common Chronic Pain Conditions in Developed and Developing Countries: Gender and Age Differences and Comorbidity with Depression-Anxiety Disorders. *J Pain*. 2008;9(10):883-889.
5. Hay SI, Abajobir AA, Abate KH, Abbafati C, Abbas KM, Abd-Allah F, et al. Global, Regional, and National Disability-Adjusted Life-Years (DALYs) for 333 Diseases and Injuries and Health Life Expectancy (HALE) for 195 Countries and Territories, 1990-2016: A Systematic Analysis for the Global Burden of Disease Study. *Lancet*. 2017;390(10100):1260-1344.
6. The World Bank. Data: Country and Lending Groups 2023-2024. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country- and-lending-groups
7. Clelland SJ, Chauhan P, Mandari FN. The epidemiology and management of tibia and fibula fractures at Kilimanjaro Christian Medical Centre (KCMC) in Northern Tanzania. *Pan Afr Med J*. 2016;25. doi:10.11604/pamj.2016.25.51.10612
8. Bhandari M, Guyatt G, Walter SD, et al. Randomized Trial of Reamed and Unreamed Intramedullary Nailing of Tibial Shaft Fractures: By the Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures (SPRINT) Investigators. *J Bone Jt Surg Am*. 2008;90(12):2567-2578.
9. O'Neill KM, Greenberg SLM, Cherian M, et al. Bellwether Procedures for Monitoring and Planning Essential Surgical Care in Low- and Middle-Income Countries: Caesarean Delivery, Laparotomy, and Treatment of Open Fractures. *World J Surg*. 2016;40(11):2611-2619.
10. Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, Ameh EA,et al. Global Surgery 2030: Evidence and Solutions for Achieving Health, Welfare, and Economic Development. *The Lancet*. 2015;386(9993):569-624. doi:10.1016/S0140-6736(15)60160-X
11. Evaniew N, Godin K, Schemitsch EH, Bhandari M. Evidence Gaps in the Global Decade of Road Traffic Safety. *J Orthop Trauma*. 2014;28(6):S15-7.
12. Challa S, Wu HH, Cunningham BP, et al. Orthopaedic Trauma in the Developing World: Where Are the Gaps in Research and What Can Be Done? *J Orthop Trauma*. 2018;32:S43. doi:10.1097/BOT.0000000000001293
13. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2014;38(8):1723-1729.
14. Brophy RH, Smith MV, Latterman C, Jones MH, Reinke EK, Flanigan DC, etc. Multi-Investigator Collaboration in Orthopaedic Surgery Research Compared to Other Medical Fields. *J Orthop Res*. 2012;30(10):1523-1528.
15. Chomsky-Higgins K, Miclau TA, MacKechnie MC, Aguilar D, Rubio Avila J, Baldy dos Reis F, et al. Barriers to Clinical Research in Latin America. *Front Public Health*. 2017;5:57. doi:10.3389/fpubh.2017.00057

16. Flores MJ, Brown KE, Pendleton MM, Albright PD, MacKechnie MC, Guerrero Rodriguez E, et al. Barriers To and Outcomes of Initiating Clinical Research at Two Trauma Centers in Mexico. *J Surg Res*. 2023;(284):1-5.
17. Escobar SCP, Costa MCD. Visibility of Latin American Scientific Publications: The Example of Bolivia. *J Sci Commun*. 2006;5:1-8.
18. Falavigna A, Filho DEM, Avila JMJ, Guyot JP, Gonzáles AS, Riew DK. Strategy to Increase Research in Latin America: Project on Education in Research by AOSpine Latin America. *Eur J Orthop Surg Traumatol*. 2015;25(1):13-20.

CHAPTER 2

Barriers to Clinical Research in Latin America

Chomsky- Higgins K[1], Miclau TA[2], MacKechnie MC[3], Aguilar D[4], Rubio Avila J[5], Baldy dos Reis F[6], Balmaseda R[7], Barquet A[8], Ceballos A[7], Contreras F[9], Escalante I[10], Elias N[11], Iriarte Vincenti S[12], Lozano C[13], Medina F[14], Merchan G[15], Segovia J[16], Guerado E[17], Quintero JE[18], Morshed S[3], Bhandari M[19], Miclau T[3]

[1]San Francisco - East Bay Surgery Program, University of California, Oakland, CA, USA
[2]Stanford University, Palo Alto, CA, USA
[3]Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology (IGOT), University of California, San Francisco, CA, USA
[4]Hospital Vivian Pellas, Managua, Nicaragua
[5]Clinical Medica Sur, Guadalajara, Mexico
[6]Federal University of Sao Paulo, Sao Paulo, Brazil
[7]Department of Orthopaedic Surgery, Centro de Investigaciones Médico-Quirúricas (CIMEQ), La Habana, Cuba
[8]Department of Traumatology and Orthopaedics, AEPSM, Montevideo, Uruguay
[9]Hospital San Juan de Dios, San José, Costa Rica
[10]Hospital Universitario de Caracas, Caracas, Venezuela
[11]Vila Velha Hospital, Espírito-Santo, Brazil
[12]Hospital San Gabriel and Clinica del Sur, La Paz, Bolivia
[13]Clínica Anglo Americana, Lima, Peru
[14]Hospital de Traumatología Instituto Mexicano del Seguro Social, Mexico City, Mexico
[15]Hospital de la Policia Nacional, Guayaquil, Ecuador
[16]Instituto de Prevision Social, Servicio de Ortopedia y Traumatologia, Asunción, Paraguay
[17]Department of Orthopaedic Surgery, Traumatology, and Rehabilitation, University of Málaga, Hospital Costa del Sol, Marbella, Málaga, Spain
[18]Hospital Universitario San Jorge, Clínica de Ortopedia y Traumatología, Pereira-Risaralda, Colombia
[19]Division of Orthopaedic Surgery, McMaster University, Hamilton, ON, Canada

Public Health Front. 2017; 5(57):1-5

Abstract
Enhancing health research capacity in developing countries is a global health priority. Understanding the orthopaedic burden of disease in Latin America will require close partnership between more-developed and less-developed countries. To this end, the Osteosynthesis and Trauma Care Foundation assembled a research consortium of Latin American orthopaedic leaders. Prior to the meeting, we surveyed attendees on perceived barriers to conducting research at their institutions. During the event, working groups discussed these barriers, developed strategies for addressing them, and planned future steps for collaboration. The participants established the need for global relationships that allow colleagues from Latin America access to training and established investigational infrastructure of North American centers to address research questions relevant to their communities. As a result of the discussion, the International Orthopaedic Multicenter Study in Fracture Care (INORMUS) was initiated. Since then, an expanded international working group, Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR), has been created with the purpose of promoting increased global partnership for research capacity development.

Introduction

Musculoskeletal conditions contribute to an increasing burden of disease throughout the world, including Latin America. The most financially and socioeconomically impactful of these conditions is musculoskeletal trauma, which is on the rise as a direct result of road traffic accidents. The World Health Organization (WHO) predicts that road traffic injuries will increase from the ninth to the third highest cause of Disability-Adjusted Life Years (DALYs) worldwide by 2030.[1] According to data from the 2013 Global Burden of Disease study, injuries have already become the fifth leading cause of DALYs.[2] As this burden continues to rise, estimates of orthopaedic injury patterns and prevalent treatment strategies in low-and middle-income countries (LMICs) become ever more important for health systems planning. Developing these estimates will require collaboration between more-developed (Global North) and less-developed (Global South) countries, as many in the latter group lack robust research infrastructure.[3,4] This results in decreased research productivity; accordingly, articles originating from Latin American countries are underrepresented in major orthopaedic surgery journals.[5,6] This is a fundamental limitation to the development of knowledge that could improve musculoskeletal injury care and inform research and policy priorities.

Many authors recognize the potential of sustainable, collaborative North-South partnerships to improve clinical research and education among LMICs.[5–14] Despite broad recognition of this issue for over two decades and the current support for institutional partnerships as a solution, there is still a persistent lack of research infrastructure in developing countries. Thus, the Council on Health Research for Development (COHRED) organized a series of meetings on Latin American health research priorities in which representatives from twenty Latin American countries agreed to implement national and regional health research programs.[15,16] While many recommendations have resulted from these high-level discussions, little information exists regarding specific barriers that could help to inform ground-level North-South partnerships in the near future. These authors could find no literature on the barriers to orthopaedic research in Latin America. To understand these specific barriers and develop the consortium, we assembled a working group of leaders from thirteen Latin American countries in a professional forum to discuss barriers faced in clinical research and to develop strategies for surmounting these obstacles.

Methods

Prior to the Osteosynthesis and Trauma Care Foundation Forum of the Americas meeting in October 2011, we sent a needs assessment document to stimulate discussion. Attendees were asked to query their colleagues in suggested areas to achieve representation from their regions. Participants from this expert working group included 15 participants representing 13 different countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Paraguay, Peru, Uruguay, and Venezuela. Additional participants from Japan, China, the Netherlands, and the United States were also invited to provide contrasting perspectives. The course Chairmen selected the surgeons based on their interests in international orthopaedic activities and commitment to improving the field of orthopaedics through research.

The areas discussed included their current role and extent of research at each participant's home institution, and their personal involvement in research activities. The meeting was conducted in English, as all of the participants also were proficient in that language. Pre-meeting questions

were circulated to stimulate discussion prior to the meeting, and comments were distributed and used in working group sessions. During these sessions, group members discussed barriers to research at their hospitals, possible strategies for overcoming these barriers, and research questions that were priorities for their patients. A scribe recorded the proceedings for each group. Finally, each group presented their findings to the entire assembly and discussed plans for collaborative research. The focus of this report is to review those barriers faced specifically in Latin America.

Results

Current research programs vary from non-existent to fairly robust. Approximately two-thirds of the participants reported that their institutions participate in research of some kind. Most also noted that research was a requirement for professional advancement, either for graduation or matriculation in a program, or for promotion or advancement within their institutions. Approximately half reported current involvement in research activities. About one-third were interested in research but not currently involved in a project, and a few noted that residents were the ones that exclusively completed research at his or her hospital. Where research was performed, most noted that the work included general topics (often initiated by residents' research questions), while some had specific areas of interest and expertise.

There was complete agreement that research capacity and interest could increase if appropriate financial and structural support were in place. Participants reported that clinical research support staff as well as financial support would likely improve the research capacity at their home institutions. Approximately half affirmed that access to scientific journals would also be a supportive measure. Other suggestions included free-of-cost trial implants, increased support from other colleagues, development of a research mentality, and establishment of a clinical database. Participants indicated that financial incentives would be a principle stimulator of interest in clinical research among colleagues at their institutions. This recognition might also come in the form of scholarships to present findings at national and international conferences. Increased access to hardware, support staff, and protected time could also be motivators. According to this group of orthopaedists, research interest would increase if there were opportunities to work collectively in multidisciplinary groups or with other research centers. Some suggested that the opportunity to answer clinical questions of relevance to their patients would be motivation enough to stimulate research activity.

Participants identified several key clinical questions and tasks for their practice settings (figures 1A&B). Topics included outcomes, cost-effectiveness, trauma burden, specific treatment queries, and quality of materials. Tasks included hospital infrastructure development, establishment of polytrauma protocols, formation of a network of trauma centers, and clinical research design. Nearly all respondents indicated interest in a clinical research symposium on the fundamentals of clinical research, and all indicated interest in receiving email updates on topics in evidence-based medicine. All affirmed that they would be interested in participating in an international multicenter research project on orthopaedic trauma.

The working groups each produced a list of anticipated or known barriers to conducting research in their settings. These lists were reviewed individually by the larger group. It was clear from these discussions that barriers exist along all steps in the research process, from unfamiliarity

with evidence-based medicine techniques to publication bias. In parallel, the working groups recommended strategies for surmounting these barriers and identified tasks for initiating the process of overcoming them (table 1).

Discussion

The international research summit provoked thought on the real challenges that potential Latin American researchers might face in performing clinical investigations in their hospitals. The groups produced a list of solutions for overcoming specifically identified barriers. The participants confirmed the need for global North-South relationships that allow South colleagues access to training and established investigational infrastructure of the North to address research questions relevant to their communities. More importantly, the process allowed for discussion around the diverse experiences of each professional, and galvanized commitment to persevere through these challenges. Though considerable published work exists on the imperative to build such partnerships, there is little writing on the methodology for doing so, particularly among surgeons.

Those present at the meeting made a commitment to collaborate on International Orthopaedic Multicenter Study (INORMUS) in Latin America. This project aligns with recommendations from the 2008 COHRED Conference for Latin American Research and Innovation for Health which advocated increased epidemiological study of the burden of disease in Latin America in order to inform resource allocation.[16] INORMUS is a short-term fracture audit that may serve as a bridge to a longer-term trauma registry. Each site will have access to the data from all sites, thus providing a database with adequate power to answer clinical questions that Latin American orthopaedists may face in their settings. We anticipate that the process of working together on this project will engender strong working relationships across institutions that the data from INORMUS will fill an important gap in burden of disease knowledge, and that implementation of the project will provide a framework for novel research infrastructure in Global South settings.

With the enthusiasm and success of INORMUS, orthopaedic surgeons involved in this project have sought to create an expanded international collaborative initiative focused on building research capacity across institutions throughout Latin America. The product of this pioneering endeavor is Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR), a consortium established to support investigative and networking opportunities across the Americas. Though only recently established, ACTUAR has already had promising responses from orthopaedists representing over 15 different countries across the Americas. The inaugural meeting of these surgeons will be held in the near future in order to discuss how this initiative can best address the barriers to conducting research in Latin America. ACTUAR aims to increase research capacity through sustainable, collaborative partnerships and to ultimately improve fracture care and to guide policy priorities.

References

1. Mathers C, Fat DM, Boerma JT. Data from: The Global Burden of Disease 2004 Update. Geneva Switzerland World Health Organization. Published online 2008. http://site.ebrary.com/id/10266345
2. GBD 2013 DALYS and HALE Collaborators, Murray CJ, Barber RM, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectance (HALE) for 188 countries, 1990-2013: Quantifying the epidemiology transition. *Lancet*. 2015;386:10000.
3. Deckelbaum RJ, Ntambi JM, Wolgemuth DJ. Basic Science Research and Education: A Priority for Training and Capacity Building in Developing Countries. *Infect Clin North Am*. 25(3):2011.
4. Dormans JP, Fisher RC, Pill SG. Orthopaedics in the Developing World: Present and Future Concerns. *J Am Acad Orthop Surg*. 2001;9(5).
5. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2013;38(1723).
6. Aluede EE, Phillips J, Bleyer J, Jergesen HE, Coughlin RR. Representation of Developing Countries in Orthopaedic Journals: A Survey of Four Influential Orthopaedic Journals. *Orthop Relat Res*. 2012;470.
7. Moraes VY, Belloti JC, Faloppa F, Bhandari M. Collaborative Multicenter Trials in Latin America: Challenges and Opportunities in Orthopaedic and Trauma Surgery. *Sao Paulo Med J*. 2013;(131):187-192.
8. Morshed S, Shearer DW, Coughlin RR. Collaborative Partnerships and the Future of Global Orthopaedics. *Clin Orthop Relat Res*. 2013;471:10.
9. Global Forum for Health Research (Organization), Davey S. The 10/90 Report on Health Research, 2003-2004. *Geneva Switz Glob Forum Health Res*. Published online 2004.
10. Barreto ML. Health Research in Developing Countries. *BMJ*. 2009;339:b4846.
11. Moreno-Borchart A. One Problem at a Time: Building Research Capacities in Developing Countries in Necessary for Economic Success in the Long Term. But the Numberous Problems in Doing So Have to Be Solved for Each Country. *EMBO Rep*. 2004;5(2).
12. Nuyens Y. Setting Priorities for Health Research: Lessons from Low-and Middle-Income Countries. *Bull World Health Organ*. 2007;85(4).
13. Beveridge M, Howard A. The Burden of Orthopaedic Disease in Developing Countries. *J Bone Jt Surg Am*. 2004;86-A(8).
14. Spiegel DA, Gosselin RA, Coughlin RR, Joshipura M, Browner BD, Dormans JP. The Burden of Musculoskeletal Injury in Low-and Middle-Income Countries: Challenges and Opportunities. *J Bone Jt Surg Am*. 2008;90(4).
15. Council on Health Research for Development | Second Latin American Conference on Research and Innovation for Health. Published online 2008. Available from http://www.cohred.org/2nd-latin-american-conference-on-research-and-innovation-for-health/
16. Council on Health Research for Development | First Latin American Conference on Research and Innovation for Health. Published online 2008. http://www.cohred.org/publications/cohred-publications/joint-publications/first-latin-american-conference-on-research-and-innovation-for-health/

Figure 1A. Key clinical questions identified by the working group

- Fragility fractures and osteometabolic disease
- Outcomes studies (and comparison to other institutions)
- Trauma burden
- Cost-effective implants
- Strategies to provide cost-effective care
- Complication rates
- Material quality
- Treatment of bony defects in long bone fractures
- Disease prevalence data

Figure 1B. Key tasks identified by the working group for development of research infrastructure

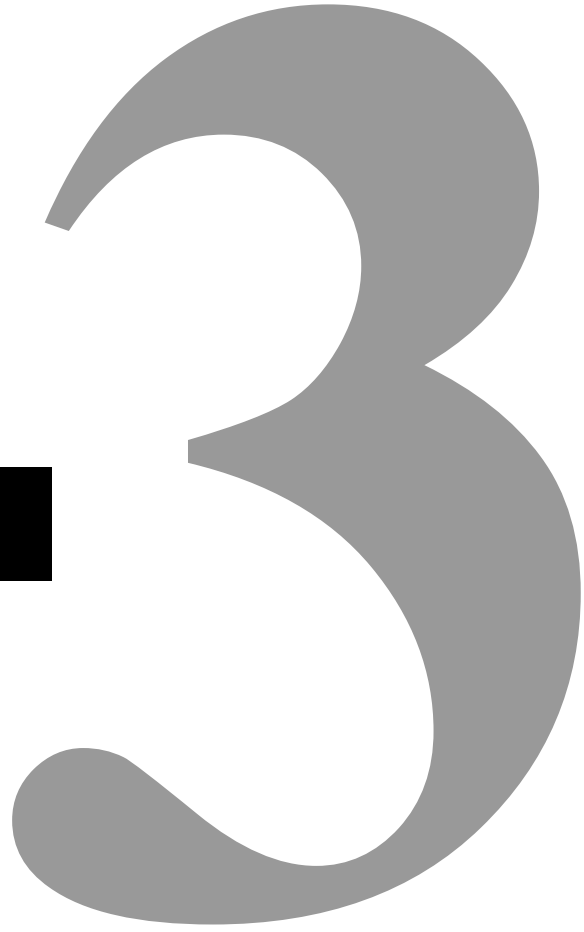
- Establishing polytrauma protocols
- Formation of a national network of trauma centers
- Stimulating residents and junior attendings to produce quality research
- How to choose a research project that will be of benefit to the local population
- Improvement of hospital infrastructure

Table 1: Barriers to research paired with potential interventions

Barrier	**Tasks to Overcome Barrier**
Lack of evidence-based medicine knowledge	Find models of EBM at conferences, in journals Target residents (who may have to complete research projects for advancement in their programs) Participate in collaborative study with a small, manageable question
Lack of journal access and/or lack of ability to read journals in English	Attempt to get access to journal articles via WHO, preferably in Spanish
Insufficient institutional interest	Target departments chiefs to achieve buy-in
Insufficient number of patients	Consider multicenter trial
Use of residents as research staff is problematic due to turnover	Consider short-term study
Lack of incentives and academic recognition makes it difficult to get physicians involved	Seek support specifically for motivating incentives or scholarships
Problematic charting makes retrospective studies difficult	Consider prospective study
Lack of funding and access to grants	Partner with University that has access to funding
Publication bias (against researchers from developing countries); local journals not particularly active	Partner with University that has access to journals
Political issues	--
Lack of support for ethics approval	Join another study with appropriate ethics approval
As patients must pay for their own implants, randomization in implant studies is not possible	Consider alternative study designs and seek donated plates
Patient follow-up is very difficult	Consider what information can be gained in a single visit
Lack of start-up funds and critical personnel	Choose a simple research question that will not require vast expenditures

Acknowledgements
We gratefully acknowledge the following participants from the Forum of the Americas meeting for providing information for the meeting or participation in the discussion groups: Carlos Amanquez, MD (Hospital General de Agudos Juan A. Fernandez, Buenos Aires, Argentina), Ernesto Besser, MD (Hospital Traumatologia University, Concepción, Chile), Baoguo Jiang, MD (University People's Hospital, Beijing, China), Thomas Lyon, MD (Lutheran Medical Center, Brooklyn, New York, USA), Peter Patka, MD (Erasmus Medical Center, Rotterdam, Netherlands), Melvin Rosenwasser, MD (Columbia University, Columbia, New York), Milan Sen, MD (Jacobi Medical Center, New York, New York, USA), Yoshi Watanabe, MD (Teikyo University School of Medicine, Teikyo, Japan), Tianbing Wang, MD (University People's Hospital, Beijing, China), and Amber Caldwell (University of California, San Francisco). We would also like to acknowledge the Osteosynthesis and Trauma Care (OTC) Foundation, and its main funding supporter, the Stryker Corporation, for funding and Richard Helmer for organizational assistance of the Forum of the Americas meeting in support of participant travel and course logistics.

CHAPTER 3



Asociación de Cirujanos Traumatólogos de las Américas [Association of Trauma Surgeons in the Americas]: Development of a Latin American Research Consortium

Miclau T[1], MacKechnie MC[1], Shearer DW[1], ACTUAR Partners[†]

[1]Department of Orthopaedic Surgery, University of California, San Francisco, Orthopaedic Trauma Institute, Institute for Global Orthopaedics and Traumatology, San Francisco, CA, USA

J Orthop Trauma. 2018; 32(7):S8-11

Abstract
Trauma continues to be a leading cause of mortality and morbidity in lower and middle-income countries (LMICs). To meet the ever-growing need of musculoskeletal care in trauma patients, orthopaedic surgeons play an instrumental role in providing care, guided by relevant clinical research studies. Promoting research and publishing results are both crucial to influencing trauma-related skeletal injury treatment in LMICs. Currently, few opportunities exist for trauma surgeons in Latin America to participate in clinical research or to contribute to academic publications, thereby limiting their ability to address potentially critical treatment questions faced by their specific patient populations. In response to these obstacles, in 2017, a group of 60 surgeon-leaders representing 18 countries throughout Latin America developed the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR; www.actuarla.org). ACTUAR supports investigative opportunities for Latin American orthopaedic trauma surgeons who want to contribute through collaborative research work. This pioneering initiative aims to improve trauma-related research, clinical care, and health care policies through the development of an international network across the Americas.

Introduction

The World Health Organization predicts that trauma will be the third largest killer in the developing world by 2020.[1,2] Worldwide, trauma is the leading cause of death in the first four decades of a person's life, surpassed only by cancer and atherosclerosis in all age groups.[3] Unfortunately, the impact of trauma is far greater; for every death attributable to trauma, three additional patients survive with permanent disability. Despite numerous advances in medicine that have helped to reduce the global impact of trauma, countries with lower Gross Domestic Products (GDPs) continue to be disproportionately disadvantaged.[4] Musculoskeletal injuries represent a large proportion of trauma burden worldwide, with the burden being greatest in LMICs.[4] For many Latin American countries, such as Mexico and Brazil, despite being classified as upper middle-income countries, wealth is highly concentrated in a small strata and not broadly distributed. Therefore, a significant proportion of their population is predisposed to conditions that are normally found in countries with a much lower GDP.[5,6] To address the relevant questions to their patient populations, clinical providers should engage in investigative work, including conducting clinical research studies and disseminating that work to others through academic publications. There are very limited opportunities for surgeons in Latin America to engage in these activities. Indeed, the volume of scientific publications is low, with Latin American surgeons only producing approximately 1% of all academic research articles in major orthopaedic journals.[7,8] One way to overcome these limited research opportunities is through increasing multinational collaboration and partnerships.[9]

The Latin American Conference on Research and Innovation for Health, organized by the Council on Health Research in Development (COHRED) and hosted in Rio de Janeiro in 2008, was the first meeting of its kind among participants from 20 Latin American countries. The goal of the meeting was to gather key partners from across Latin America, including ministries, research institutes, and non-governmental organizations, to discuss research challenges in various national health research systems and examine ways to best foster future collaborations in health research and patient care.[10] The level of participation and enthusiasm from Latin American participants was high and inspired numerous other similar meetings. A follow-up conference was held in 2008 in Havana, Cuba, and another Latin American Conference took place in Panama City, Panama in 2011.

Rationale for ACTUAR

In 2011, the Osteosynthesis and Trauma Care Foundation organized a "Forum of the Americas" conference in Miami, Florida, USA, and 15 representatives from Latin American countries attended the meeting. Before the meeting, the orthopaedic researchers completed a pre-course needs assessment survey to highlight the specific challenges that attendees faced when performing clinical investigations in their own institutions. Participants identified a number of barriers that they confronted in their research, including deficiencies in resources and deficits in institutional support. The results from the needs assessment questionnaires revealed significant differences between participants. For example, Cuban orthopaedic surgeons reported that they, in general, have adequate infrastructural support such as satisfactory hospitals and clinics, yet they report a deficit in the necessary tools and training to critically interpret scientific information in clinical research.[8,11] This conference opened up new avenues for supporting and sharing learning and research among Latin American orthopaedic surgeons dedicated to the care of musculoskeletal injuries and served as a catalyst to form the Asociación de Cirujanos

Traumatólogos de las Américas (ACTUAR) in 2017 (Figure 1). ACTUAR aims to advance the clinical care of musculoskeletal injuries in Latin America by disseminating an understanding of research methodology and promoting collaborative research opportunities in conjunction with leading academic departments in North America. The international research consortium currently includes more than 60 members from 18 countries across North, South, and Central America, representing Argentina, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Nicaragua, Panama, Paraguay, Peru, Spain, the United States of America, Uruguay, and Venezuela.

In the 2011 needs assessment survey distributed before the "Forum of the Americas" conference, orthopaedic trauma surgeons reported leading obstacles to conducting research: a lack of financial support from academic institutions, including limited funding and insufficient access to grants; few incentives to engage in and present findings at conferences; and inadequate numbers of research support staff.[12] Other surgeons reported that their institutions lacked investigative infrastructures, such as online database technologies available to multiple centers.[12] Participants reported an interest in working collectively in multidisciplinary groups with other research centers, confirming the need for global North-South relationships that allow surgeons from across the Americas to access already established investigational infrastructure, including the training and resources, of North America. This involvement would allow surgeons to better address the research questions that are the most relevant to their own communities.[11] According to a study on Latin American articles published in the orthopaedic literature, Urritia et al. found that most orthopaedic surgeons in Latin America do not have the financial support to conduct studies of publishable quality in high-impact journals.[7] This limits Latin American researchers' opportunities to present their results at international forums, and this further restricts the discussion of their data and research.[4] In addition, because articles published in most major orthopaedic journals are written in English, the language barrier may impede the dissemination of research that is conducted in Spanish- or Portuguese-speaking Latin America. These barriers impede the development of knowledge about Latin American orthopaedic issues, impact the care of patients with musculoskeletal injuries, and inhibit research and policy priorities throughout the region.

Future Directions

Understanding some of the difficulties associated with research in Latin America has enabled ACTUAR to develop strategies to address identified needs. One such strategy to increase research programs and publications by Latin American surgeons was through an inaugural ACTUAR Research Symposium held in October 2017 in San Luis Potosí, Mexico (Figure 2). The symposium was held in conjunction with the national annual FEMECOT (Federacion Mexicana de Colegios de Ortopedia y Traumatologia) Convention. It consisted of a one-and-a-half day meeting that included 24 leaders from 10 countries, including the Latin American countries of Brazil, Cuba, Colombia, Panama, Paraguay, Peru, Mexico, and Venezuela and connected faculty from the University of California, San Francisco (UCSF) and from McMaster University in Canada. The symposium addressed basic clinical research designs and multi-center participant research requirements to participate in a project at surgeons' own institutions. In addition, the group identified a research topic that could be used as a pilot to begin a preliminary research project. Because the ACTUAR member's institutions and centers have varying levels of familiarity and experience with conducting clinical research, the research project selected needed

to be of broad interest and limited complexity to maximize individuals' abilities to participate. The first project will be directed at open tibia fracture management, with the Department of Orthopaedic Surgery and Orthopaedic Trauma Institute at the UCSF serving as the central hub for data collection. The second annual ACTUAR symposium, will take place in Mérida, Mexico in October 2018 and will be dedicated to addressing obstacles encountered by individual centers.

ACTUAR group members have organized monthly meetings to communicate progress on individual projects, and a newly developed website will enhance further communication between the members (www.actuarla.org). The website features a database of members and their projects, with the goal of facilitating member exchanges. The expectation is that, through ACTUAR, all members will have the opportunity to participate in a range of studies and eventually, all participants will be able to publish or contribute to publications of their findings in a high-impact orthopaedic trauma journals. While having centers participate in the multi-center studies and produce publications in major orthopaedic journals represent one metric of success, the major impact will likely be the infrastructure created by participating in research work and the culture change that recognizes the impact of these contributions within and beyond the ACTUAR members' institutions and organizations.

As funding remains a significant barrier, ACTUAR has been fortunate to receive support for its first three years from the Wyss Medical Foundation to UCSF's Institute for Global Orthopaedics and Traumatology (IGOT). This funding provides for the development of the website, a Research Symposium, and the conduct of an international, multi-center research study. It will also allow for ACTUAR to support those members who would like to participate in its activities, but would otherwise not be able to because of financial barriers.

Conclusion

Enhancing health research engagement and capacity in developing countries is a global health priority, as sharing findings and knowledge about optimal treatments to meet regional needs can ultimately improve the care of patients with musculoskeletal injuries. Involving Latin American orthopaedic academic trauma surgeons in educational and research collaborations with colleagues within well-developed infrastructures enhances those surgeons' abilities to promote original, scientific research and promotes the development of additional skills in a region ready for advancement. The Asociación de Cirujanos Traumatólogos de las Américas is a novel group that seeks to grow capacity in clinical investigation throughout Latin America and address health care issues relevant to their patient populations.

References

1. World Health Organization. Global Status Report on Road Safety: Time for Action. *Geneva World Health Organ*. Published online 2009. http://www.who.int/violence_injury_prevention/road_safety_status/report/cover_and_front_matter_en.pdf
2. Fraser B. Traffic Accidents Scar Latin America's Roads. *Lancet Lond Engl*. 2005;366(9487):703-704.
3. Croce MA, Livingston DH, Luchette FA, et al. *American Association for the Surgery of Trauma*.; 2013.
4. Haagsma JA, Graetz N, Bollinger I, Naghavi M, Higashi H, Mullany EC, et al. The Global Burden of Injury: Incidence, Mortality, Disability-Adjusted Life Years and Time Trends from the Global Burden of Disease Study. *Inj Prev*. 2013;22(1):3-18. doi:10.1136/injuryprev-2015-041616
5. World Bank and Lending Groups. Published online 2018. Accessed April 24, 2018. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
6. Henandez GE. Extreme Inequality in Mexico: Concentration of Economic and Political Power. *Rep OXFAM*. Published online 2015. http://www.socialprotectionet.org/sites/default/files/inequality_oxfam.pdf
7. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2014;38(8):1723-1729.
8. Falavigna A, Botelho RV, Teles AR, et al. Twelve Years of Scientific Production on Medline by Latin American Spine Surgeons. *PLoS ONE*. 2014;9(2). doi:10.1371/journal.pone.0087945
9. Moraes VY, Belloti JC, Faloppa F, Bhandari M. Collaborative Multicenter Trials in Latin America: Challenges and Opportunities in Orthopaedic and Trauma Surgery. *Sao Paulo Med J*. 2013;(131):187-192.
10. COHRED. Council on Health Research for Development. Second Latin American Conference on Research and Innoivation for Health. Published online 2011. http://www.cohred.org/2nd-latin-american-conference-on-research-and-innovation-for-health/
11. Miclau TA, Chomsky-Higgins K, Ceballos A, Balmaseda R, Morshed S, Bhandari M, et al. Building Surgical Research Capacity Globally: Efficacy of a Clinical Research Course for Surgeons in Low-Resource Settings. *Front Educ*. 2017;2(57). doi:https://doi.org/10.3389/feduc.2017.00057
12. Chomsky-Higgins K, Miclau TA, MacKechnie MC, Aguilar D, Rubio Avila J, Baldy dos Reis F, et al. Barriers to Clinical Research in Latin America. *Front Public Health*. 2017;5:57. doi:10.3389/fpubh.2017.00057

Figure 1. Inaugural ACTUAR in-person meeting at American Academy of Orthopaedic Surgeons (AAOS) in San Diego, CA, USA in 2017.

Figure 2. Inaugural ACTUAR research symposium in San Luis Potosi, Mexico in 2018.

Acknowledgements

†ACTUAR Partners (Corporate Authorship)

Dino Aguilar, MD (Hospital Vivian Pellas), Luz Gerardo Aguilar, MD (Instituto Mexicano del Seguro Social), Jorge Rubio Avila, MD (Medica Sur), Roberto Balmaseda, MD (Hospital Central de Investigaciones Medico Quirurgicas), William D. Belangero, MD (State University of Campinas, UNICAMP), Ricardo Camacho (Hospital Matadei de Belem), Alfredo Ceballos Mesa, MD (Hospital Universitario Gral Calixto Garcia), Ivaldo Angelo Cintra Jr., MD (Hospital Maradei), Hernando Cuevas, MD (Instituto Mexicano del Seguro Social), Nelson Elias, MD (Escola Superior de Ciencias da Santa Casa de Misericordia de Vitoria), Igor A. Escalante E., MD (Universidad Central de Venezuela), Antonio Flores, MD (Universidad Guadalajara, Lamar), Mario Garuz (Hospital Santo Tomas), Fernando de la Huerta, MD (Instituto Mexicano del Seguro Social), Nicolas Lee, MD (University of California, San Francisco), Roberto E. Lopez Cervantes, MD (Cruz Roja Mexicana Delegacion Guadalajara), Christian Lozano, MD (Clinica Anglo Americana), Monica Martinez Sanchez, MD (Instituto Mexicano del Seguro Social), Gerardo Lopez Mejia, MD (Hospital Christus Muguerza Saltillo), Edgar E. Mercado Salcedo, MD (Instituto Mexicano del Seguro Social), Saam Morshed, MD, PhD (University of California, San Francisco), Luis G. Padilla Rojas, MD (Federacion Mexicana de Colegios de Ortopedia y Traumatologia AC), Carlos G. Sanchez Valenciano, MD (Hospital Universitario de Caracas), Julio Segovia, MD (Hospital Central de IPS), Sheila Sprague, PhD (McMaster University), Horacio Tabares, MD (Centro de Investigaciones en Longevidad, Envejecimiento y Salud), Miguel Triana, MD (Hospital Infantil de San Jose y Clinical la Colina), Manuel G. Ylizaturri, MD (Hospital Christus Muguerza Saltillo)

CHAPTER 4

4

Leadership Development for Orthopaedic Trauma Surgeons in Latin America: Opportunities for and Barriers to Skill Acquisition

MacKechnie MC[1], MacKechnie MA[2], Van Lieshout EMM[3], Verhofstad MHJ[3], Quintero JE[4], Padilla LG[5], Tabares Neyra H[6], Dello Russo B[7], Giordano V[8], Vilensky E[9], Fuehrer SL[10], Miclau T[1], ACTUAR Study Group[†]

[1]Orthopaedic Trauma Institute, Institute for Global Orthopaedics and Traumatology, Department of Orthopaedic Surgery, University of California, San Francisco, School of Medicine, Zuckerberg San Francisco General Hospital, San Francisco, California
[2]Department of Orthopaedic Surgery, Cleveland Clinic Martin Health, Stuart, Florida
[3]Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands
[4]Fracturas y Fracturas, Pereira-Risaralda, Colombia
[5]Puerta de Hierro Hospital, Zapopan, Jalisco, Mexico
[6]Center of Research on Longevity, Aging, and Health (Centro de Investigaciones en Longevidad, Envejecimiento, y Salud), CITED, Cuban Society of Orthopaedics and Traumatology (Sociedad Cubana de Ortopedia y Traumatología), Vedado GP, La Habana, Cuba
[7]National Hospital of Pediatrics, Professor J.P Garrahan (Hospital Nacional de Pediatria, Profesor J.P. Garrahan), Buenos Aires, Argentina
[8]Orthopaedics and Traumatology Service, Professor Nova Monteiro, Municipal Hospital Miguel Couto, Leblon, Rio de Janeiro, Brazil
[9]Casmu, Spanish Association, General Bulevar Artigas (Asociación Española, Bulevar General Artigas), Montevideo, Uruguay
[10]University of North Carolina at Chapel Hill, School of Medicine, Chapel Hill, North Carolina

Abstract

Introduction: There is growing interest in leadership courses for physicians. Few opportunities are available in global regions with limited resources. This study describes orthopaedic trauma surgeons' desired leadership skill acquisition, opportunities, and barriers to course participation in Latin America.

Methods: Latin American orthopaedic trauma surgeons from the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR) network were surveyed. This survey solicited and gauged the surgeons' level of interest in leadership topics and their relative importance utilizing a 5-point Likert-scale. Additionally, comparisons were calculated between middle-income countries (MICs) and high-income countries (HICs) to ascertain if needs were different between groups. The survey included demographic information, nationality, level of training, years in practice, leadership position, needs assessment, and perceived barriers for leadership educational opportunities.

Results: One hundred and forty-four orthopaedic surgeons completed the survey, representing 18 countries across Latin America; 15 MICs and 3 HICs. Participants had more than 20 years in practice (49%) and held leadership positions (81%) in hospital settings (62%), national orthopaedic societies (45%), and/or clinical settings (40%). Sixty-three percent had never attended a leadership course due to lack of opportunities/invitations (69%), difficulty missing work (24%), and costs (21%). Ninety-seven percent expressed interest in attending a leadership course. No difference in needs was determined between respondents from MICs and HICs. Professional Ethics, Crisis Management/Organizational Change Management, and High Performing Team-Building were identified as the most important leadership topics.

Conclusion: Orthopaedic surgeons in Latin America demonstrate an interest in acquiring additional leadership skills but have few opportunities. Identifying interests, knowledge gaps, and core competencies can guide the development of such opportunities.

Introduction

There is a recognized need for non-clinical leadership courses for surgeons.[1–4] Such courses promote strong personal and professional values, including interprofessional networking, the development of organizational and communicative skills, and the ability to mentor; all of which are regarded as integral to ensuring organizational success and promoting the delivery of high-quality care.[5–7] While these skills are commonly taught in modern leadership development programs for surgeons in high-income countries (HICs),[8] there is a relative paucity of literature on leadership programs in low-and middle-income countries (LMICs), particularly in the case of surgeons in Latin America.

In a highly specialized field such as orthopaedic surgery, the need for surgeons to function as leaders in their various roles is becoming more widely recognized.[9–11] Surgeons in modern-day practice must effectively communicate in the operating room and clinic, collaborate, teach, facilitate learning, manage teams, and lead advocacy efforts.[7,12,13] Despite surgeons often being positioned to take an active leadership role within their practice, dedicated leadership education is rarely a part of their training.[14,15] Few studies have explored educational leadership needs specific to orthopaedic surgeons in Latin America, thereby limiting the development of effective curricula that adequately address the needs of this particular group. Understanding the challenges associated with participating in such programs and assessing areas of need can help to strengthen the capacity of organizations and improve the performance of surgeon-leaders. Characterizing the skills one would desire to obtain from such a program, and incorporating region-specific perspectives into the curricula, are key steps for guiding the delivery of future programs and helping create models for collaboration among orthopaedic surgeons.

This paper describes the leadership skills and expertise that orthopaedic surgeons in Latin America view as necessary to better serve as leaders in their field, as well as barriers to participating in leadership development activities. Identifying knowledge gaps in leadership development training and the core competencies considered to be the most important and interesting for such programs can guide the development of future curricula for orthopaedic surgeons in Latin America.

Methods

This cross-sectional, multi-national survey was conducted between March and September 2019 to gauge Latin American orthopaedic surgeons' level of interest in various leadership topics and their relative importance. The Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR) network was utilized for this study. ACTUAR is an international, collaborative consortium aimed at building research capacity among orthopaedic trauma surgeons in Latin America,[16] and all practicing orthopaedic surgeon-members were invited to participate in the study. The survey was developed by author consensus and reviewed by three independent academic experts in clinical research (Appendix A).

Questions were directed at understanding perceived areas of need as well as preferred leadership topics in an effort to guide effective future leadership program curricula. The ten leadership topics that were assessed in the survey were chosen based on major themes identified in a review of the literature and formal leadership programs from major business schools, including the Kellogg School of Management and the University of Southern California School of Business.[17–

[21] The survey consisted of 43 questions that included demographic information, gender, nationality, level of training, years in practice, current leadership position, and a needs assessment on perceived barriers to leadership education opportunities. The survey was translated into Spanish using a back-translation method[22] and distributed electronically to participants using Research Electronic Data Capture (REDCap), an established secure patient information database tool. This study was designated as exempt from review by the University of California, San Francisco Institutional Review Board.

Statistical Analysis

Descriptive statistics were reported to summarize surgeons' needs and perceived level of interest and importance in non-clinical leadership topics utilizing a weighted mean from a 5-point Likert scale (1= Strongly Agree, 2= Agree, 3= Undecided, 4= Disagree, 5= Strongly Disagree). In addition, comparisons between country income-levels determined by the World Bank 2019-2020 Country and Lending Groups data were calculated to ascertain if perceived importance and interests of leadership topics were different between surgeons in middle-income countries (MICs) and high-income countries (HICs).[23] Analysis was performed using the 2-tailed Fisher exact test with $p < 0.05$ as the significance level and was conducted using STATA SE version 16.1 (STATACorp, College Station, TX).

Results

Demographics

The survey was completed by 144 orthopaedic surgeons out of 213 total who were invited to participate, demonstrating a 68% response rate. Respondents represented 18 countries, of which 15 are categorized as MICs, and three as HICs. No statistically significant differences in orthopaedic surgeons' needs were determined between income-level groups, however, one difference ($p= 0.04$) was identified between the perceived level of interest in the leadership topic on Management of Social Networking.

The greatest proportion of participants were male (89%), with more than 20 years in practice (49%) and had held a leadership position (81%) for more than six years (51%). The respondents reported holding formal leadership roles, broadly defined as a position that manages people or makes decisions that influences others. Respondents reported holding leadership positions as presidents or board members of professional orthopaedic organizations, supervisors, professors, or self-identified mentors within their orthopaedic practice. These positions were reported in various capacities: hospital settings (62%), national orthopaedic societies (44%), and/or clinical settings (40%). Fewer participants indicated that they held a leadership role within a regional society (27%) or an international orthopaedic society (8%).

Needs Assessment

The majority of participants reported never having attended a leadership course (63%), with only 19% of participants having attended two or more leadership programs throughout their careers as orthopaedic surgeons. Less than a sixth of participants (15%) reported having previously taken a leadership assessment personality test (e.g. Myers-Briggs Type Indicator or Gallup Strengths Finder) (Table 1). Ninety-seven percent of participants expressed interest in attending a leadership course and most were comfortable attending a course instructed in the English language (90%). The main barriers to attending such courses were lack of opportunities or

invitations (69%), difficulty missing work (24%), cost (21%), and calendar conflicts (17%). Furthermore, interactive plenary sessions (68%), small group work (62%), and simulation exercises (58%) were reported as the three most desirable and engaging learning methods (Table 2).

The majority of respondents (96%) strongly agreed/agreed that they felt they had the essential qualities to be a leader, with only 3% of respondents' undecided, and only one respondent (1%) who disagreed with this statement. In response to the question on awareness of the qualities that make leadership successful, the respondents strongly agreed/agreed (87%) with this comment. Fewer respondents were undecided (12%), and only two respondents (2%) strongly disagreed.

In addition, on a Likert-scale questionnaire, the three topics rated as the most important leadership topics were Professional Ethics, Crisis Management/Organizational Change Management, and High Performing Team-Building. The most interesting leadership topics were Professional Ethics, High Performing Team-Building, and Organizational Structure and Ability to Lead (Figure 1). A comparison analysis illustrates the difference in ratings between participants in MICs and HICs (Table 3). No significant differences were identified in leadership topics when stratified by surgeons' experience.

Discussion

Leadership education for surgeons has proven effective in promoting organizational success and facilitating the development of skills integral to surgeons' overall clinical expertise.[7,24,25] Despite this recognition, there is a dearth of publications describing studies of leadership programs for surgeons in Latin America. Therefore, LMICs in Latin America often rely on literature largely derived from HICs in North America and Europe. Identifying the perceived needs for leadership courses specific to Latin American orthopaedic surgeons can help to promote the development of leadership opportunities and effective curricula which adequately address the needs of this particular group.

In this study, one statistically significant difference was observed between income groups regarding orthopaedic surgeons' perceived level of interest in leadership topics. Consistent with this finding, prior research has shown that leadership programs from HICs are often unlikely to apply well to LMICs. A study from the oncology field compared 217 Latin American oncology surgeon-leaders' perceptions on leadership competencies to those from North America and Europe.[26] Notably, the most valued leadership skills identified among the Latin American respondents were significantly different from those identified by North American and European respondents. Additionally, another study noted important differences in the value of leadership education competencies between physicians and other healthcare professional groups.[27] Factors such as culture, language, resources, training, and surgical subspecialty may influence the perception of desired leadership topics. This illustrates the importance of developing and tailoring leadership curriculum to specific professions and regions.

According to the survey respondents in this study, the three leadership topics considered to be most important were Professional Ethics, Crisis Management/Organizational Change Management, and High Performing Team-Building. Additionally, the three highest rated leadership topics considered to be most interesting were Professional Ethics, High Performing

Team-Building, and Organizational Structure and Ability to Lead. These topics embody the multi-faceted aspects of surgeons' roles as leaders, from managing teams to collaborating and leading quality improvement or advocacy efforts, and may be used as core concepts in the development of future leadership curricula. Though non-medical, another study demonstrated similar desirable leadership traits in Latin American managers, including decisiveness, diplomacy, collaboration, and altruism.[28] Overall, the majority of Likert-scale results were positively scored by the survey respondents, with a disproportionately small percentage of leadership topics perceived as not important or interesting. While this could highlight a shared appreciation for leadership-related content for orthopaedic surgeons, the overwhelming positive Likert-scale responses could also reflect a degree of unfamiliarity with the specificity of these topics.

Further, the majority of survey respondents served in a leadership position within the field of orthopaedic surgery, many with over 20 years of experience; yet, relatively few had taken a leadership course. While there is clearly a need for leadership programs for these surgeons, prior studies show that experiential learning over time can still lead to effective faculty development.[29] However, further investigation on the relationship between experience and course work is important. One systematic review that identified key leadership competencies for medical professionals determined that these skills could best be acquired through formal, systematic education, such as graduate studies; although there are many barriers to this type of training.[30]

An overwhelming 97% of Latin American respondents expressed interest in attending a leadership course designed for orthopaedic surgeons, however, multiple barriers to participating in such programs were identified. This included lack of opportunities/invitations, time constraints, and cost. Due to an orthopaedic surgeon's demanding schedule, with an average of 70 hours of work per week,[31] the ease of having time to attend courses outside of work is low. One pilot study proposed a solution by building a mandatory leadership training program into the curriculum for medical specialists.[15] The idea of mandatory leadership training for all surgeons was positive, with 81% of the participants stating that participation in a leadership course led them to feel better prepared to tackle and learn from challenges. These personal development skills are important characteristics for highly successful orthopaedic surgeons,[31] and promoting mandatory, standardized leadership programs in conjunction with orthopaedic surgeons' institutional training could help equip surgeons with skill sets that can improve performances and reinforce best practices. Additional leadership course resources such as personality assessment tests, though more embraced in the business field, can also be an effective tool in improving physician leadership and mentorship skills for orthopaedic programs.[32] This evidence suggests that orthopaedic surgery leadership development programs have the potential to be extremely beneficial not only to surgeons but also to their patients and health systems.

The results of this needs assessment survey can be used to develop leadership training curricula, ideally accessible to all orthopaedic surgeons in Latin America. In an effort to alleviate barriers identified in the survey, the leadership development opportunities could be offered free of cost through an online platform to allow for accessible and self-paced training. This online offering could be supplemented by local courses delivered by surgeon-leaders with an interest and expertise in identified areas for leadership development. In addition, the findings of this study can help foster awareness and encourage the development of leadership opportunities in this region, as well as contribute to the literature on orthopaedic trauma care in Latin America, which

has historically been underrepresented.[33,34] The surgeon-respondents represented all Spanish-speaking countries in Latin America, allowing for a more uniform view of the region's needs. Almost 70% of respondents completed the survey, representing a strong response rate. Given its success, this type of survey-based study can be used as a model for future needs assessments, targeting surgeons with other subspecialities or geographical areas.

The study has several limitations. The needs assessment survey was restricted to self-reported measures. However, this study represents an important first step in gauging appropriate topics for leadership curricula, as a needs assessment approach is an effective way to understand knowledge gaps that ultimately create programs that meet those needs. Additionally, the orthopaedic surgeon participants were from the ACTUAR network, which includes a substantial number of members who are experienced orthopaedic trauma surgeons who have held leadership positions within their national societies and have an interest in conducting research. Therefore, these participants represent only one small segment of the diverse population of orthopaedic surgeons in Latin America and may not fully represent the views of the general population, potentially creating a selection bias. While not all ACTUAR members have experience in research or have engaged in significant leadership roles, the organization does attract individuals with an interest in developing these areas professionally and regionally. Given this interest, members of the ACTUAR network represent a group of orthopaedic surgeons familiar with academic society offerings and existing leadership development activities and are, therefore, an appropriate group to gauge perceived needs in these areas. Finally, in this study, females only represent 11% of the orthopaedic surgeon-participants. Few published reports address the overall representation of female orthopaedic trauma surgeons in Latin America. One study cited that females represented 4.8% of all orthopaedic traumatologists in Peru and 6% of the national orthopaedic and traumatology society in Chile.[35] Therefore, the current study likely does not underrepresent female respondents.

In summary, orthopaedic surgeons in Latin America demonstrate an interest in acquiring additional leadership skills but have few opportunities. This study can help to elucidate knowledge gaps in leadership training and guide the development of curricula tailored to address the needs of this particular group. Further work is needed to better understand perceived leadership skill needs in different regions and cultures and evaluate the effectiveness of leadership programs to improve long-term leadership skills.

Acknowledgements

†ACTUAR Study Group (Corporate Authors)

Acosta Marrero L, MD (Hospital General Docente Camilo Cienfuegos); Aguilar D, MD (Centro de Ortopedia Hospital Vivian Pellas, Managua, Nicaragua); Alvarez C, MD (Clínica Pediátrica, Bogotá, Colombia; Alvarez Benito O, MD (Hospital Universitario General Calixto García); Alvarez Lopez A, MD (Hospital Universitario Manuel Ascunce Domenech); Amigo Castañeda P, MD (Hospital Provincial Pediátrico Eliseo Noel Camaño, Universidad de Ciencias Médicas de Matanzas, Cuba); Amadei Enghelmayer R, MD (Hospital San Martin, La Plata, Argentina); Arturo Xicará J, MD (Centro Universitario de Occidente, Universidad de San Carlos de Guatemala); Baldy F, MD (UNIFESP); Balmaseda Manent R, MD (Hospital Orthopaedic Fructuoso Rodriguez, Cuba); Belangero WD, MD (State University of Campinas, UNICAMP, Faculty of Medical Science Orthopaedic and Traumatology Department); Bañuelos R, MD (Federación Mexicana de Colegios de Ortopedia y Traumatología, FEMECOT); Barquet A, MD (Universidad CLAEH, Uruguay); Bidolegui F, MD (Servicio de Ortopedia y Traumatología, Hospital Sirio Libanes, Buenos Aires, Argentina); Bolaños R, MD (Hospital El Pilar); Bonilla J, MD (Hospital Universitario San Jorge, Clínica Fracturas y Fracturas); Calderon Gamba J, MD (Hospital Universitario de Santander); Camaro P, MD (Universidad Industrial de Santander-Hospital Universitario de Santander); Carabelli G, MD (Hospital Italiano de Buenos Aires, Argentina); Cárdenas Quintero R, MD (Hospital Central de San Cristóbal); Ceballos Mesa A, MD (Universidad Medica de La Habana); Chavarro Forero Y, MD (Clinica Rosales); Cucalon R, MD (Clínica de Fracturas SAS Palmira, Colombia); Delgado López JA, MD (Hospital Pediátrico Pedro Agustín Pérez, Guantánamo, Cuba); Dello Russo B, MD (Hospital Nacional Pediatria Profesor J.P. Garrahan); Elias N, MD (Vila Velha Hospital, Espírito Santo Brasil); Esteves Pires R, MD (Universidade Federal de Minas Gerais); Estrada Tellez DA, MD (Hospital Civil Fray Antonio Alcalde); Filomeno P, MD (Hospital de Clínicas); Flores-Biard A, MD (Hospital Comunitario de Jocotepec); Gaggero N, MD (Hospital del Trabajador); Galaz R, MD (Hospital Centro Medico Tuxpan); Garabano G, MD (Hospital Británico); Garuz MI, MD (Hospital Santo Tomas); Giordano V, MD (Servicio de Ortopedia e Traumatologia, Prof. Nova Monteiro, Hospital Municipal Miguel Couto, Rio de Janeiro, Brazil); Gomez Gelvez A, MD (Hospital Universitario de la Samaritana, Bogotá, Colombia); Gutiérrez-Mendoza I, MD (Unidad Médica Integral); Henrique Penteado da Silva L, MD (Clinica IOT de Passo Fundo Hospital São Vicente de Paulo); Hernández Vivas G, MD (Instituto Hondureño de Seguridad Social Hospital del Valle); Izaguirre A, MD PhD (Hospital Medica Universidad, Universidad Autónoma de Tamaulipas); Jiménez Avila JM, MD (Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Guadalajara, Jalisco, Mexico); Kojima KE, MD (Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de Sao Paulo, SP, Brasil); López Cervantes RE, MD (Hospital de Especialidades San Francisco de Asís); Lourenco PR, MD (Hospital Quinta D'Or Rio de Janeiro, Brasil); Madrigal Gutiérrez R, MD (Hospital Puerta de Hierro/Servicios Médicos Municipales Cruz Verde, Guadalajara, Mexico); Martínez de Leon U, MD (UMAE 189 IMSS Vera Cruz Hospital de María); Martínez Estupiñan LM, MD (Hospital General Universitario Mártires del 9 de Abril); Martínez Islas L, MD (Institute Mexicano del Seguro Social); Martinez Ruiz JJ, MD (Hospital Civil Fray Antonio Alcalde, Universidad de Guadalajara); Martinez Sanchez M, MD (Instituto Mexicano del Seguro Social); Medina C, MD (IPS Universitaria Clínica León XIII); Medina-Rodríguez F, MD (Hospital de Traumatología Magdalena de las Salinas, Instituto Mexicano del Seguro Social); Mejia Lopez G, MD (Hospital Christus Muguerza Saltillo); Minguer Vargas S, MD (Hospital Regional Presidente Juarez

Issste); Minueza T, MD (Hospital Fundación Ruth Paz); Morales Piñeiro SV, MD (Hospital Universitario "Mártires del 9 de Abril" Sagua la Grande, Villa Clara, Cuba); Osma Rueda JL (Universidad Industrial de Santander, SCCOT); Padilla Dieste A, MD (Christus Muguerza Alta Especialidad); Pancorbo Sandoval EA, MD (Hospital Dr. Mario Muñoz Monroy de Matanzas); Pereira S, MD (Hospital Sirio Libanes, Buenos Aires, Argentina); Pérez Lugo Y, MD (Hospital Clínico Quirúrgico Camilo Cienfuegos); Pesciallo C, MD (Hospital Británico de Buenos Aires); Quintero Hernandez S, MD (Hospital de la Santisima Trinidad); Quintero Laverde J, MD (Departamento de Ortopedia y Traumatología Hospital Universitario Clínica San Rafael); Ramírez Guevara C, MD (Hospital Puerta de Hierro, Guadalajara, México); Rio MW, MD (Clínica Zabala); Rivero Hernández JF, MD (Hospital Clínico Quirúrgico "Freyre Andrade"); Rodríguez López J, MD (Centro de Investigación y Docencia en Ciencias de la Salud, Universidad Autonoma de Sinaloa); Romero CA, MD (Instituto Salvadoreño del Seguro Social); Salazar M, MD (Hospital Central "Dr. Ignacio Morones Prieto"); Salce I, MD (Clínica Delgado AUNA); Sánchez Concepción R, MD (Clínica Central Cira Garcia); Sánchez Valenciano CG, MD (Centro Medico de Caracas, Caracas, Venezuela); Segovia J, MD (Instituto de Prevision Social); Sepulveda Oyervides VM, MD (Hospital Regional del ISSSTE, Monterrey, Nuevo Leon, México); Serrano AJ, MD (Universidad Central de Venezuela Facultad de Medicina Escuela José María Vargas Catedra de Traumatología); Tabares Sáez H, MD (Hospital Universitario "General Calixto Garcia", La Habana, Cuba); Taggesell Fischer S, MD (Universidade Federal do Paraná/ Hospital do Trabalhador); Toledo-Infanson V, MD (Hospital General Agua Prieta, Secretaría de Salud, Servicios de Salud Sonora); Triana M, MD (Fundación Cardioinfantil y Hospital Infantil de San Jose, Bogota, Colombia); Velarde Bouche JE, MD (Hospital Santo Tomás); Ylizaliturri M, MD (Christus Muguerza Hospital Saltillo); Zuluaga M, MD (Clínica Imbanaco, Cali, Colombia)

References

1. Reinertsen JL. Physicians as Leaders in the Improvement of Health Care Systems. 1998;128:833-838.
2. Frenk J, Chen L, Bhutta ZA, et al. Health Professionals for a New Century: Transforming Education to Strengthen Health Systems in an Interdependent World. *The Lancet*. 2010;376:1923-1958.
3. Schwartz RW, Pogge C. Physician Leadership is Essential to the Survival of Teaching Hospitals. *Am J Surg*. 2000;179(6):462-468.
4. Jaffe GA, Pradarelli JC, Lemak CH, et al. Designing a Leadership Development Program for Surgeons. *J Surg Res*. 2016;200(1):53-58.
5. Levine WN, Braman JP, Gelberman RH, et al. Mentorship in Orthopaedic Surgery - Road Map to Success for the Mentor and the Mentee. *J Bone Jt Surg*. 2013;95(e59):1-5. doi:http://dx.doi.org/10.2106/JBJS.L.01047
6. Collins J. Level 5 Leadership. The Triumph of Humility and Fierce Resolve. *Harv Bus Rev*. 2001;79(1):66-76.
7. McKimm J and Lieff SJ. Medical Education Leadership. In: *A Practical Guide for Medical Teachers. Chapter 42.* Churchill Livingstone-Elsevier; 2013:343-351.
8. Frich JC, Brewster AL, Cherlin EJ, et al. Leadership development programs for physicians: a systematic review. *J Gen Intern Med*. 2015;30(5):656-674. doi:10.1007/s11606-014-3141-1
9. Chen TY. Medical leadership: An important and required competency for medical students. *Tzu Chi Med J*. 2018;30(2):66-70. doi:10.4103/tcmj.tcmj_26_18
10. Peters W, Picchioni A, Fleshman JW. Surgical Leadership. *Clin Colon Rectal Surg*. 2020;33(4):233-237.
11. Angood P, Birk S. The value of physician leadership. *Physician Exec*. 2014;40:6-20.
12. Kuo CC, Robb W. Critical Roles of Orthopaedic Surgeon Leadership in Healthcare Systems to Improve Orthopaedic Surgical Patient Safety. *Clin Orthop Relat*. 2013;471:1792-1800. doi:10.1007/s11999-012-2719-3
13. Williams N, Chen M, Curtis Lee A, et al. What are the perceptions of orthopaedic surgeons regarding leadership and leadership training? *ANZ J Surg*. 2020;90(1-2):12-14.
14. Fry H. Equipping Surgeons as Educators. *ANZ J Surg*. Published online 2009:186-191.
15. Ramani S, Leinster S. AMEE Guide No. 34: Teaching in the Clinical Environment. *Med Teach*. 2008;30(4):347-364.
16. Miclau T, MacKechnie MC, Shearer DW, et al. Asociacion de Cirujanos Traumatologos de las Americas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl 7:S8-S11. doi:10.1097/BOT.0000000000001302
17. Sadowski B, Cantrell S, Barelski A, et al. Leadership training in Graduate Medical Education: A Systematic Review. *J Grad Med Educ*. 2018;10(2):134-148.
18. Guo KL. Core Competencies of the Entrepreneurial Leader in Health Care Organizations. *Health Care Manag*. 28(1):19-29.
19. Stoller JK. Developing physician-leaders: key competencies and available programs. *J Health Adm Educ*. 2008;254:307-328.
20. Kirkpatrick SA, Locke EA. Leadership: do traits matter? *Acad Manage Exec*. 5(48-60):1991.
21. Pidgeon K. The keys for success: Leadership core competencies. *J Trauma Nurse*. 2017;24(6):338-341.

22. Brislin RW. Back-Translation for Cross-Cultural Research. *J Cross-Cult Psychol*. 1970;1(3):185-216.
23. The World Bank. Data: Country and Lending Groups 2020. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
24. Shubeck SP, Kanters AE, Dimick JB. Surgeon Leadership Style and Risk-Adjusted Patient Outcomes. *Surg Endosc*. 2019;33(2):471-474.
25. Lee TC, Reyna C, Shah SA, et al. The road to academic surgical leadership: Characteristics and experiences of surgical chairpersons. *Surgery*. 2020;168(4):707-713. doi:10.1016/j.surg.2020.05.022
26. Mano MS, Gomes R, Werutsky G, et al. Cross-Cultural Validity Study of a Medical Education Leadership Competencies Instrument in Latin American Physicians: A Multinational Study. *J Glob Oncol*. 2019;5:1-9. doi:10.1200/JGO.19.00243
27. Citaku F, Violato C, Beran T, et al. Leadership Competencies for Medical Education and Healthcare Professions: Population-Based Study. *BMJ Open*. 2012;2(e000812):1-9.
28. Ogliastri E, McMillen C, Altschul C, et al. Culture and Organizational Leadership in 10 Latin American Countries: The Globe Study. *Acad Rev Latinoam Adm*. 2006;22:29-57.
29. Steinert Y, Mann K, Centeno A, et al. A Systematic Review of Development Initiatives Designed to Improve Teaching Effectiveness in Medical Education. *Med Teach*. 2006;28(6).
30. Violato C, Cawthorpe D. Core Research Competencies for Scholars and Researchers in Medical Education: an MSc and PhD Program. In: *Research in Medical Education - Chances and Challenges.* Vol 20. German Medical Science GMS Publishing House; 2009.
31. Klein G, Hussain N, Sprague S, et al. Characteristics of highly successful orthopedic surgeons: A survey of orthopedic chairs and editors. *Can J Surg*. 2013;56:192-198.
32. Tornetta P, Jacobs JJ, Sterling RS, et al. Personality Assessment in Orthopaedic Surgery: AOA Critical Issues. *J Bone Joint Surg Am*. 2019;101(4):e13-e13. doi:10.2106/JBJS.18.00578
33. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2013;38(1723).
34. Challa S, Wu H-H, Cunningham BP, et al. Orthopaedic Trauma in the Developing World: Where Are the Gaps in Research and What Can Be Done? *J Orthop Trauma*. 2018;32:S43. doi:10.1097/BOT.0000000000001293
35. Arias C, Bytyqui D, Chokotho L, et al. Diversity in Orthopaedics and Traumatology: A Global Perspective. *EFORT Open Rev*. 2020;5:743-752.

Figure 1. Participant response rate gauging surgeons' level of interest in leadership topics and their relative importance utilizing Likert-scale survey questions based on percentage of responses among overall group.

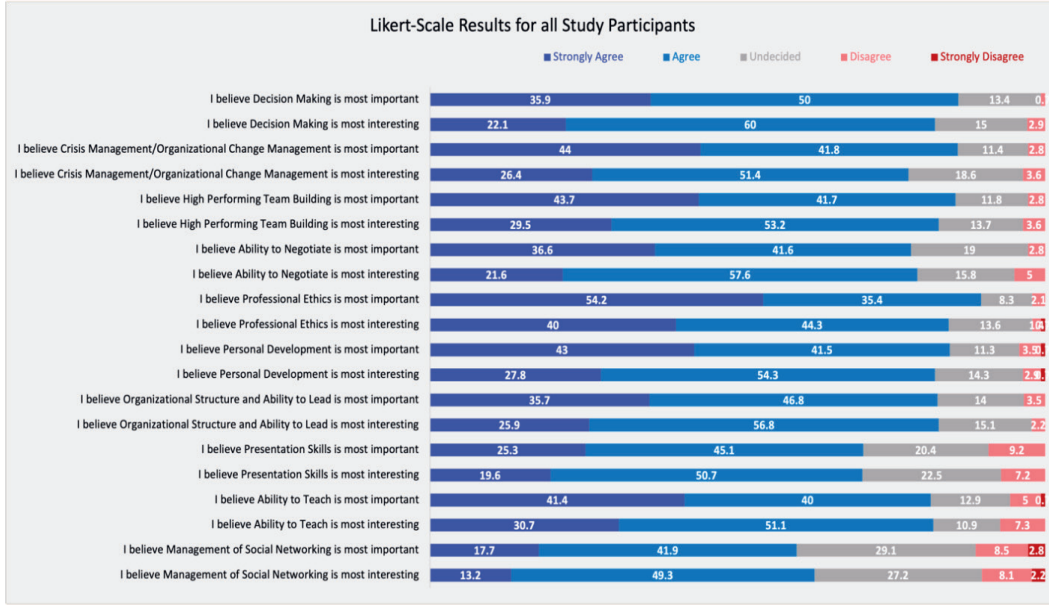


Table 1. Demographic data of survey respondents

Characteristic	**N (%)**	**Middle-Income Country (MIC)^**	**High-Income Country (HIC)^**
Total	*144 (100)*		
Gender			
Male	127 (89)		
Female	17 (11)		
Country of practice			
Argentina		9 (6)	
Bolivia		1 (1)	
Brazil		12 (8)	
Chile			1 (1)
Colombia		28 (19)	
Cuba		25 (17)	
Dominican Republic		1 (1)	
Ecuador		1 (1)	
El Salvador		3 (2)	
Guatemala		4 (3)	
Honduras		4 (3)	
Mexico		38 (27)	
Nicaragua		3 (2)	
Panama			2 (1)
Paraguay		1 (1)	
Peru		2 (1)	
Uruguay			6 (4)
Venezuela		3 (2)	
Years in practice			
0-5	11 (8)		
6-10	17 (12)		
11-15	18 (12)		
16-20	28 (19)		
More than 20	70 (49)		
Currently hold a leadership position?			
Yes	117 (81)		
No	27 (19)		
Years in a leadership position			
0-2	28 (24)		
3-5	29 (25)		
More than 6	60 (51)		
Leadership role+			
Hospital setting	89 (62)		
National orthopaedic society	64 (44)		
Clinical setting	58 (40)		
Regional orthopaedic society	39 (27)		
International orthopaedic society	11 (8)		

*Various demographic data not reported for all respondents

+Multiple responses selected

^2021 World Bank Country and Lending Groups

Table 2. Leadership Course Needs Assessment

Questions	**N (%)**
Total	*144 (100)*
How many leadership courses have you attended previously?	
None	91 (63)
1	26 (18)
2 or more	27 (19)
Interested in attending a leadership course for surgeons?	
Yes	139 (97)
No	5 (3)
Are you comfortable taking a leadership course in English?	
Yes	129 (90)
No	15 (10)
Have you ever taken a personality test?	
No	122 (85)
Yes	22 (15)
Main obstacles to attending a leadership course[+]	
No opportunities or invitations	99 (69)
Difficulty missing work	35 (24)
Cost	30 (21)
Calendar conflicts	25 (17)
Other	11 (8)
Early in career	4 (3)
Teaching methods that are the most engaging[+]	
Interactive plenary session	98 (68)
Small group work	90 (62)
Simulation exercises	83 (58)
Lectures	76 (53)
Other	2 (1)

*Various demographic data not reported for all respondents
[+]Multiple responses selected

Table 3. Comparison analysis between middle-income countries (MICs) and high-income countries (HICs)

	MIC Mean	SD	HIC Mean	SD	P-Value
The Most *Important* Leadership Topic Is:					
Decision Making	1.78	0.70	1.75	0.46	0.43
Crisis Management/Organizational Change Management	1.75	0.78	1.5	0.53	0.82
High Performing Team-Building	1.74	0.79	1.67	0.71	>1.0
Ability to Negotiate	1.88	0.84	1.78	0.44	0.13
Professional Ethics	1.57	0.75	1.67	0.50	>1.0
Personal Development	1.78	0.84	1.75	0.89	0.28
Organizational Structure and Ability to Lead	1.85	0.80	1.63	0.52	0.77
Presentation Skills	2.11	0.90	2.38	0.92	0.71
Ability to Teach	1.83	0.87	1.75	1.20	0.25
Management of Social Networking	2.34	0.94	2.62	1.40	0.28
The Most *Interesting* Leadership Topic Is:					
Decision Making	2.0	0.72	1.89	0.33	0.52
Crisis Management/Organizational Change Management	1.98	0.79	2.0	0.50	0.62
High Performing Team-Building	1.88	0.77	2.25	0.46	0.13
Ability to Negotiate	2.03	0.78	2.12	0.35	0.41
Professional Ethics	1.78	0.80	1.87	0.64	0.68
Personal Development	1.93	0.79	2.12	0.64	0.61
Organizational Structure and Ability to Lead	1.91	0.72	2.12	0.35	0.27
Presentation Skills	2.13	0.83	2.62	0.74	0.29
Ability to Teach	1.94	0.84	2.0	0.93	0.65
Management of Social Networking	2.34	0.89	2.56	1.10	0.04

*All tests of significance are completed with Fisher's exact test ($p < 0.05$)
Weighted mean using a 5-point Likert-scale; 1 = strongly agree, 2 = agree, 3 = undecided, 4 = disagree, 5 = strongly disagree

Appendix A (Supplemental Digital Content)
The cross-sectional survey design is available at http://links.lww.com/OTAI/A21

CHAPTER 5

Building Leadership Development Capacity for Orthopaedic Surgeons in Latin America

MacKechnie MC[1], Padilla Rojas LG[2], de la Huerta F[3], Lopez Almejo L[4], Gomez JM[5], Quintero Hernandez S[6], Miclau T[7], Leadership Development Group[†]

[1]Orthopaedic Trauma Institute, Department of Orthopaedic Surgery, University of California, San Francisco, Zuckerberg San Francisco General Hospital, San Francisco, California
[2]Hospital Puerta de Hierro, Zapopan, México
[3]Unidad de Ortopedia y Traumatología, Guadalajara, México
[4]Federación Mexicana de Colegios de Ortopedia y Traumatología, A.C. Aguascalientes, México
[5]Sanatorio San Francisco de Asis, Guadalajara, México
[6]Universidad de Guadalajara, Guadalajara, México

Orthotips. 2021;17(4):57- 62

Abstract
Solutions to address the global burden of musculoskeletal trauma in Latin America require not only financial resources and clinical research infrastructure, but also non-clinical leadership capacity-building for orthopaedic surgeons. Recognizing the impact that leadership development training has on improving patient outcomes and performance of healthcare organizations, orthopaedic surgeons in Latin America could greatly benefit from these opportunities. Yet, formal training or opportunities to attend such programs, particularly in countries with limited resources, largely do not exist. Most of the literature describing leadership programs is concentrated on high-income countries (HICs), specifically in North America and Europe. As a result of this discrepancy, the network of orthopaedic trauma surgeons, Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR), developed curricula for a novel Leadership Development Program (LDP) for Latin American orthopaedic surgeons. This paper describes the delivery of the one-day LDP delivered to 40 orthopaedic trauma surgeons at the 30th Annual Federación Mexicana de Colegio de Ortopedía y Traumatología (FEMECOT) Congress in Hermosillo, México on October 31, 2019.

Introduction

Musculoskeletal conditions contribute to an increasing burden throughout the world.[1] According to the World Health Organization, Latin America has the highest per capita road traffic fatality rates than any region worldwide.[2] Latin America, which comprises diverse healthcare systems with varying resources across countries,[3] has a relative absence of region-specific research examining the burden of musculoskeletal trauma. This lack of investigative work originating from Latin America contributes to the overall paucity of credible data on the burden of musculoskeletal conditions in low- and middle-income countries (LMICs).[4] Region-specific solutions to address this burden require not only financial resources and research infrastructure, but also leadership capacity-building for orthopaedic surgeons. Recognizing the impact that leadership development training has on increasing patient outcomes and performance of healthcare organizations, orthopaedic surgeons in Latin America could greatly benefit from these opportunities.[5–9]

Non-clinical leadership competencies, such as emotional intelligence, self-awareness, effective communication, problem-solving skills, and the ability to coach and mentor others, are common characteristics expected in the surgical field. Yet, formal training or opportunities to attend such programs, particularly in countries with more limited resources largely do not exist;[10–12] most of the literature describing leadership programs is concentrated on high-income countries (HICs), specifically in North America and Europe.[11] As a result of this discrepancy, the Latin American network of orthopaedic trauma surgeons, Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR; www.actuarla.org), developed curricula for a novel Leadership Development Program (LDP) for Latin American orthopaedic surgeons. The purpose of this course was to complement the personal and professional skills of orthopaedic surgeons' drive to lead with the expertise needed to do so effectively. The LDP can be adapted and utilized as a model by local orthopaedic surgeons in resource-limited environments.

This paper describes the delivery of the one-day LDP delivered to 40 orthopaedic trauma surgeons at the 30th Annual Federación Mexicana de Colegio de Ortopedía y Traumatología (FEMECOT) Congress in Hermosillo, México on October 31, 2019.

Background

There is a disparity in the number of scientific publications arising from Latin America, particularly within the trauma subspecialty;[13] indeed, Latin American countries represented only 1% of orthopaedic articles, and only 3.1% of orthopaedic trauma studies originating from Latin America were represented among all LMICs.[13,14] This deficiency is significant considering the importance of locally-produced research in the development of effective healthcare infrastructure.[15,16] Professional enrichment opportunities such as leadership development are instrumental in developing avenues for knowledge exchange and capacity-building.[17–19] One solution to this is through building multi-national partnerships that promote the efforts of collaborative investigative work and leadership infrastructure. To this end, the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR) was developed in 2017 to foster partnerships and facilitate networking between the Global North-South.[20] Since its establishment, ACTUAR has grown to over 150 members and partnered with more than 20 academic societies throughout the region. With the overarching goal to increase research capacity across North,

South, and Central America, ACTUAR works to further develop infrastructure for collaboration with these surgeons as collaborators, co-investigators, and co-authors.

Engaging and supporting leadership capacity-building would appear to be an effective strategy towards improving patient outcomes and treatment. Currently, few leadership development opportunities exist for orthopaedic surgeons in Latin America to participate in non-clinical, competency courses, thus limiting their ability to enhance their skills as a leader. Given that many ACTUAR members hold formal and informal leadership roles as board members for national and international orthopaedic societies and as mentors to orthopaedic trainees within their clinical practices, leadership development training could greatly impact these surgeon-leaders, both personally and professionally.

As a result, in 2019, ACTUAR members and faculty from the University of California, San Francisco (UCSF) and FEMECOT collaborated on the design of a one-day leadership course, to be offered at one of the largest annual orthopaedic conferences in Latin America. Given the relative absence of leadership program models for orthopaedic surgeons, the main organizers of the course were tasked with building a curriculum that was tailored to orthopaedic surgery for relevance and applicability.

Leadership Course

On October 31, 2019, 40 orthopaedic surgeons from three countries (Colombia, Cuba, México) attended the one-day LDP in Hermosillo, México, held in conjunction with the 30th Annual FEMECOT Congress. Attendees were orthopaedic surgeons selected based on their experience and roles as leaders within their professional orthopaedic societies or clinical practices. In preparation for the course, the attendees were given a needs assessment survey to query their level of interest and importance in leadership topics, perceived accelerators and barriers to attending leadership development opportunities, as well as demographic information.[21] The leadership topics and themes identified from the survey results guided the organizers' selection of LDP course content.

The LDP schedule consisted of multiple teaching methods, including didactics, small working groups, and interactive group activities (Appendix A), and was developed in line with the "70-20-10" rule to foster effective leadership skills.[22,23] Ten percent of the curriculum involved formal instruction and classroom-based learning concepts, 20% involved small-group discussion and feedback, and 70% involved experiential learning and applying their new skills to real-world experiences. This was also achieved through an interactive group activity and instruction was delivered by local surgeon-leaders with an interest and expertise in selective areas of leadership development (Figure 1). Course curricula was designed by identifying key themes and topics from Latin American-focused literature reviews,[17,24–27] formal leadership programs from major business schools in the United States, and recommendations solicited from experts. The curriculum included concepts designed to impart fundamental principles of leadership development; specifically, critical elements of leadership, styles of personal learning, communication, team dynamics, and hands-on pedagogical activities, including a case study and an interactive group activity. All course instruction was in Spanish.

Future Directions

The one-day intensive LDP, presented by local faculty on the fundamentals of leadership, could be a long-term effective method to support leadership development capacity, and ultimately, improve treatment of musculoskeletal trauma care in diverse populations across Latin America.

Future directions could include: 1) transitioning the LDP to an online modular curriculum to allow for accessible, self-paced training and an amplified impact with a wider reach of surgeons; 2) adapting the course for other subspecialities or geographical regions, particularly in LMICs that are often lacking these professional development opportunities; 3) maintaining a sustainable model by including local surgeon-leaders as educators with an interest and expertise in leadership; 4) expanding the LDP by creating a series of complementary courses to be delivered annually at future FEMECOT Congresses; and 5) assessing and measuring the knowledge retention and course impact through pre-and post-knowledge surveys.

Conclusions

In summary, the LDP was designed to enlighten orthopaedic surgeons in senior leadership positions across Latin America who are poised to impact the specialty today and in the future. This type of course curriculum could continue to enrich surgeons' development of non-clinical leadership skills, increase their knowledge of leadership concepts and principles, facilitate networking, and reinforce Global North-South partnerships. The goal of this course was to develop a sustainable and effective model and equip orthopaedic trauma surgeons in Latin America with the necessary leadership skills, and ultimately advance high-quality musculoskeletal care. While there are many clear benefits to non-clinical leadership development training in the medical field, further investigation into evidenced-based and region-specific impact of a LDP is necessary to better direct the curricula for future courses.

References

1. Murray CJL, et. al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. 2012;380(9859):2197-2223
2. World Health Organization. Global status report on road safety: time for action. Geneva: World Health Organization. Published online 2009. Accessed December 19, 2020. https://apps.who.int/iris/bitstream/handle/10665/44122/9789241563840_eng.pdf;jsessionid=52695470F483BBEB25BFC5685C7FDC04?sequence=1
3. Padilla Rojas LG, Lopez Cervantes RE, Perez Atanasio JM, Sanchez MM, Gomez Acevedo JM, Kodima KE. Latin America Trauma Systems - Mexico and Brazil. *OTA Int*. 2019;2(S1):e020
4. Joshipura M, Gosselin RA. Surgical Burden of Musculoskeletal Conditions in Low- and Middle-Income Countries. *World J Surg*. 2020;44(4):1026-1032. doi:10.1007/s00268-018-4790-8
5. Lerman C. and Jameson L. Leadership Development in Medicine. *New Engl J Med*. 378(20):1862-1863
6. Frenk J, Chen L, Bhutta ZA, Cohen J, Cris N, Evans T, Fineberg H, et al. Health Professionals for a New Century: Transforming Education to Strengthen Health Systems in an Interdependent World. *The Lancet*. 2010;376:1923-1958
7. Reinertsen JL. Physicians as Leaders in the Improvement of Health Care Systems. 1998;128:833-838
8. Rotenstein LS, Sadun R, Jena AB. Why Doctors Need Leadership Training. *Harv Bus Rev*. Published online October 17, 2018
9. Baker GR, Macintosh-Murray A, Porcellato C, et al. High Performing Health Care Systems: Delivering Quality by Design. In: Longwoods; 2008
10. Lobas JG. Leadership in Academic Medicine: Capabilities and Conditions for Organizational Success. *Am J Med*. 2006;119(7):617-621
11. Frich JC, Brewster AM, Cherlin EJ, Bradley EH. Leadership Development Programs for Physicians: A Systematic Review. *J Gen Intern Med*. 2014;30(5):656-674
12. Alpert JS. Leadership in Academic Medicine. *Am J Med*. 2010;123:1072-2
13. Challa S, Wu H-H, Cunningham BP, et al. Orthopaedic Trauma in the Developing World: Where Are the Gaps in Research and What Can Be Done? *J Orthop Trauma*. 2018;32:S43
14. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2013;38(1723).
15. Nuyens Y. No Development Without Research: A Challenge for Research Capacity Strengthening. Accessed June 20, 2021. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.files.ethz.ch/isn/128224/2005-ResearchReport-NoDevelopment.pdf
16. Minja H, Nsanzabana C, Maure C, et al. Impact of Health Research Capacity Strengthening in Low- and Middle-Income Countries: The Case of WHO/TDR Programmes. *PLoS Negl Trop Dis*. 2011;5:e1351
17. Miclau TA, Chomsky-Higgins K, Ceballos A, et al. Building Surgical Research Capacity Globally: Efficacy of a Clinical Research Course for Surgeons in Low-Resource Settings. *Front Educ*. 2017;2(57). doi:https://doi.org/10.3389/feduc.2017.00057

18. Prado A, Figueroa L, Barry C, Bertelsen, N. Management Training in Global Health Education: A New Health Innovation Fellowship in Central America. *Glob Health Action*. 2018;11(1):1-9. doi:https://doi.org.10.1080/16549716.2017.1408359
19. Hoppe B, Reinelt C. Social network analysis and the evaluation of leadership networks. *Leadersh Q*. 2010;21:600-619
20. Miclau T, MacKechnie MC, Shearer DW, et al. Asociacion de Cirujanos Traumatologos de las Americas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl 7:S8-S11.
21. MacKechnie MC, MacKechnie MA, Van Lieshout EMM, et al. Leadership Development for Orthopaedic Surgeons in Latin America: Opportunities for and Barriers to Skill Acquisition. *OTA Int*. 2021;4(4):e146-53
22. Rosch DM, Jenkins DM. What Do We Know About Formal Leadership Courses and Their Effects? In: *Evidence-Based Practices to Strengthen Leadership Development*. ; 2020:31-41.
23. Eichinger B, Lombardo M. Center for Creative Leadership: Lessons of Experience. Accessed June 20, 2021. https://www.ccl.org/articles/leading-effectively-articles/70-20-10-rule/
24. Chomsky-Higgins K, Miclau TA, MacKechnie MC, et al. Barriers to Clinical Research in Latin America. *Front Public Health*. 2017;5:57
25. Wu E, Singh M, Le PV, Dandu M, Duderstadt K, Brock T, et al. Global Health Bootcamp: An Innovative Interprofessional Course for Clinicians Dedicated to Equitable Global Health Care Delivery. *Ann Glob Health*. 2015;81(1):60-61
26. Steinert Y, Naismith L, Mann K. Faculty Development Initiatives Designed to Promote Leadership in Medical Education. A BEME Systematic Review. *Med Teach*. 2012;34(6):483-503
27. Mano MS, Gomes R, Werutsky G, et al. Cross-Cultural Validity Study of a Medical Education Leadership Competencies Instrument in Latin American Physicians: A Multinational Study. *J Glob Oncol*. 2019;5:1-9

Figure 1. Dr. Fernando de la Huerta of Guadalajara, México delivered a presentation on effective communication at the Inaugural Leadership Development Program for Orthopaedic Surgeons in Hermosillo, Mexico, October 31, 2019.

Acknowledgements

†Leadership Development Group (Corporate Authors)

Banuelos Benites R (Universidad Panamericana, Aguascalientes, México); Gutiérrez Mendoza I (Médico con Práctica Privada); Izaguirre A (Universidad Autónoma de Tamaulipas); Jiménez Avila JM (Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Guadalajara, Guadalajara, Jalisco, México); Lopez-Cervantes RE (Hospital San Francisco de Asis); López Estrada D (Hospital Dr. Gustavo A Rovirosa Pérez Secretaria de Salud de Tabasco); López-Mejia G (Hospital Christus Muguerza Saltillo); Martínez De León U (IMSS UMAE 14 Veracruz Hospital de María Veracruz, Hospital de María, Veracruz), Martinez Islas L (Federación Mexicana de Colegios de Ortopedia y Traumatología AC); Minguer Vargas S (Hospital Regional Presidente Juárez del ISSSTE); Quintero JE (Hospital Universitario San Jorge, Clínica Fracturas y Fracturas, Colombia); Rodríguez López J (Centro de Investigación y Docencia en Ciencias de la Salud de la Universidad Autónoma de Sinaloa); Salcido Reyna MV (Hospital General de Mexicali); Tabares Neyra H (Centro de Investigaciones en Longevidad, Envejecimiento y Salud (CITED)); Tafoya-Arreguin GA (Antiguo Hospital Civil de Guadalajara "Fray Antonio Alcalde"); Toledo-Infanson T (Hospital General Agua Prieta, Servicios de Salud Sonora); Vargas SL (IMSS Hospital 83, Morelia, Michoacán, México)

PART II

Clinical Research: Regional Priorities

CHAPTER 6

6

Establishing Consensus on Essential Resources for Orthopaedic Trauma Care Worldwide: A Modified Delphi Study

MacKechnie MC[1], Shearer DW[1], Verhofstad MHJ[2], Martin C[3], Graham SM[4,5], Pesantez R[6], Huttl T[7], Schuetz M[8], Kojima K[9], Bernstein BP[10], Miclau T[1], Delphi Study Group[†].

[1]University of California, San Francisco, Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[2]Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center, Rotterdam, Rotterdam, The Netherlands
[3]AO Alliance Foundation, Davos, Switzerland
[4]Oxford Trauma and Emergency Care, Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, United Kingdom
[5]Liverpool Orthopaedic and Trauma Service, Liverpool University Teaching Hospital Trust, Liverpool, United Kingdom
[6]Fundación Santa Fe de Bogotá, Universidad de los Andes, Department of Orthopedic Surgery, Bogotá, Colombia
[7]AO Foundation, AOTrauma International, Davos, Switzerland
[8]Queensland University of Technology, Herston, Queensland, Australia
[9]Universidade de Sao Paulo, Sao Paulo, Brazil
[10]Division of Orthopaedic Surgery, University of Cape Town, Cape Town, South Africa

J Bone Joint Surg Am. 2023. Epub ahead of print

Abstract

Background: Despite evidence that formalized trauma systems enhance patient functional outcomes and decrease mortality rates, there remains a lack of these systems globally. Critical to trauma systems are the equipment, materials, and supplies needed to support care, which vary in availability regionally. The purpose of this study was to identify essential resources for musculoskeletal trauma care across diverse resource-settings worldwide.

Methods: The modified Delphi method was utilized, with three-rounds of electronic surveys. Respondents consisted of one surgeon per country with expertise in musculoskeletal trauma. Participants were identified using the AO Trauma, AO Alliance, Orthopaedic Trauma Association, and European Society for Trauma and Emergency Surgery networks. Respondents rated resources on a Likert scale from 1 (most important) to 9 (least important). The "most essential" resources were classified as those rated ≤2 by ≥75% of the sampled group.

Results: 103 of 111 invited surgeons completed the first survey and were included throughout the subsequent rounds (93% response rate). Most participants were fellowship-trained (78%) trauma and orthopaedic surgeons (90%) practicing in an academic setting (62%), with over 20 years of experience (46%). Respondents represented low-income and lower-middle-income countries (LMICs; 35%), upper-middle income countries (UMICs; 30%), and high-income countries (HICs; 35%). The initial survey identified 308 unique resources for pre-, in-, and post-hospital phases of care, of which 71 resources achieved consensus as the most essential. There was a significant difference ($p<0.0167$) in ratings between income groups for 16 resources, all of which were related to general trauma care rather than musculoskeletal injury management.

Conclusions: There was agreement on a core list of essential musculoskeletal trauma care resources by respondents from LMICs, UMICs, and HICs. All significant differences in resource ratings were related to general trauma management. This study represents a first step towards establishing international consensus and underscores the need to prioritize resources that are locally available. The information can be used to develop effective guidelines and policies, create best-practice treatment standards, and advocate for necessary resources worldwide.

Level of Evidence: This study utilized the Delphi method representing expert opinion, however, this work did not examine patient management and therefore does not have a clinical Level of Evidence.

Introduction

Trauma is a leading cause of morbidity and mortality worldwide, with musculoskeletal injury representing a large proportion of this burden overall.[1,2] According to the World Health Organization (WHO), more than four million deaths are attributed to traumatic injuries annually.[3] While trauma impacts all populations, injury patterns vary widely by region, disproportionately affecting those in low- and middle-income countries (LMICs) where 90% of injury-related deaths occur.[1,4] Unsafe conditions, less access to resources, and lack of standardized treatment efforts contribute to this disparity.[5] Strategies to address this burden include trauma systems and established guidelines. Despite evidence that coordinated trauma systems enhance functional patient outcomes, decrease mortality rates of treated trauma patients by 15-20%, and provide support for improved allocation of resources,[1,5–7] there remains a lack of formalized systems globally.[8–10] A recent study indicated that only 29% of surgeons worldwide, and only 50% of those in high-income countries (HICs), reported that their country had a trauma system.[8] Critical to these systems are the equipment, materials, and supplies needed to deliver musculoskeletal care, which vary in availability regionally. Given the breadth of geographic and economic differences globally, recommendations for trauma care from higher-income to lower-income countries are not always generalizable. Understanding the most high-yield and locally available resources for musculoskeletal injury management across all income groups is necessary for the development of guidelines for trauma care in any given region. Thus, the purpose of the present study was to identify the most essential resources for musculoskeletal trauma care across diverse resource-settings worldwide.

Materials and Methods

Modified Delphi Method

A three-round electronic survey was administered in the English language to a panel of trauma and orthopaedic surgeons with use of the modified Delphi method. This iterative process seeks consensus opinion through a series of surveys among a group of experts. Over the last two decades, this method has become an increasingly valuable tool used to enhance decision-making processes in the field of health research.[11,12] The current study involved three survey rounds: (1) an initial survey to identify a list of essential musculoskeletal trauma care resources, (2) a second survey to rate the list of essential resources identified in the initial survey, and (3) a third survey to re-rate the list of the most essential resources identified in the second survey. Feedback on the panel's aggregate rating was provided during each survey round to help the individual surgeons re-evaluate their opinions against those of the group.

The group of experts were practicing surgeons in a leadership role (e.g., leaders of professional societies, academic orthopaedic departments, or clinical practices) who treated traumatic musculoskeletal injuries and had knowledge of the status of their country's trauma systems. All surgeons self-identified as being capable of understanding and completing a survey in the English language. One hundred and eleven surgeon-experts from 111 different countries, representing varying income groups, were invited to participate in the study. These respondents were identified using the AO Trauma, AO Alliance, Orthopaedic Trauma Association (OTA), and European Society for Trauma and Emergency Surgery (ESTES) networks and were recognized as being surgeon-leaders within their countries. Each survey was open for completion for six weeks and was administered electronically through REDCap (Research Electronic Data Capture), a secure web-based application for online surveys and databases. The study was

approved by the institutional review board at the University of California, San Francisco (UCSF) and participant consent was obtained at the time the survey was administered.

Delphi Round One
The purposes of the Round One survey were to collect the surgeons' demographic information and to develop a comprehensive list of resources considered essential for pre-hospital, in-hospital, and post-hospital phases of care for musculoskeletal injury with use of a free-text response field. The panelists were encouraged to identify a minimum of five resources for each phase of hospital care.

Delphi Round Two
All free-text responses from the Round One survey were compiled and synthesized into appropriate categories and were reviewed by the steering committee, which included a total of ten trauma and orthopaedic surgeons from Africa, Australasia, Europe, North America, and South America. These responses were subsequently distributed through an electronic survey in which the panelists were asked to review each resource and rate its perceived importance on a 9-point Likert scale (scores of 1 to 3 being "most important", 4 to 6 being "moderately important", and 7 to 9 being "least important"). The steering committee defined "most important" as a resource that should be considered a standard for the surgeon's national trauma system. In contrast, the steering committee defined "least important" as a resource that should not be included as a standard for the surgeon's national trauma system. All participants were encouraged to submit any additional resources that were considered of importance and that were not already included after the Round One survey.

Delphi Round Three
The overall mean for each resource was scored and listed by category from most important to least important in the electronic survey. Each resource was accompanied by a histogram illustrating the panelists' average rating. With the knowledge of the group's responses, the surgeons were invited to reassess their opinions and re-rate each resource against those of the group.

Statistical Analysis and Ranking
The results in the Delphi Round Three survey were summarized with an aggregate rating. The criterion for the achievement of consensus was initially defined as a rating of 1 to 3 on the Likert scale ("most important") by ≥75% of panelists, based on a threshold commonly used to define consensus.[13] However, because of the large number of resources that qualified for inclusion, a post hoc modification was made by the steering committee to set the criterion to a rating of 1 or 2 on the Likert scale with ≥75% agreement among the group. This modification allowed for the identification of only the highest ranked, or most essential, resources.

In addition, a comparison analysis of the surgeons' ratings was performed across income levels defined by the 2021 World Bank and Lending Groups data.[14] Summary statistics were calculated with use of the Wilcoxon rank sum test and the Kruskal Wallis test, with $p<0.0167$ as the significance level (due to a Bonferroni adjustment for the three pairwise comparisons among income groups). Adjustments for multiple testing across variables were not performed, as each

variable was independent. All analyses were conducted with use of Stata SE (version 17; StataCorp).

Source of Funding: This study was supported by funding from the Wyss Medical Foundation.

Results

The initial survey was completed by 103 of 111 invited respondents, yielding an overall response rate of 93%. Of these 103 respondents, 101 completed the subsequent two survey rounds (Figure 1). Participants represented countries across all income groups: low-income countries and lower-middle-income countries (LMICs; 35%), upper-middle income countries (UMICs; 30%), and high-income countries (HICs; 35%) (Figure 2).

Most respondents were fellowship-trained (78%) orthopaedic surgeons (90%) practicing in an academic setting (62%), and 46% had over 20 years of experience (Table 1). Given the networks from which the participants were selected, few (3%) identified as a surgeon practicing in a specialty other than orthopaedic surgery (e.g., general surgeons who treated trauma and musculoskeletal injuries). The initial survey yielded a total of 308 unique resources for pre-hospital, in-hospital, and post-hospital phases of care (see Appendix). Seventy-one of these resources were identified as "most essential" and were associated with the following categories: pre-hospital care (ancillary services, personnel, and supplies), in-hospital care (training, education, personnel, policies, protocols, supplies, emergency department, operating room, and infrastructure), and post-hospital care (personnel and supplies) (Table 2).

Comparison Between Income Groups

Among the full list of 308 resources identified, there were significant differences ($p<0.0167$) in ratings between income groups (LMICs, UMICs, and HICs) for 16 resources, which were designated under the following categories: pre-hospital care (ancillary services and infrastructure), in-hospital care (personnel, research, supplies, and infrastructure), and post-hospital care (community education). These resources included air medical access, general and psychiatric practitioners, advanced imaging, and anesthesia-related supplies and equipment (ventilator, intubation supplies, analgesia) (Table 3).

In all three phases of care, surgeons from lesser-resourced countries rated most of these resources as having significantly lower priority relative to those from higher-resourced countries. One exception was seen in the in-hospital personnel category; these personnel included research assistants, general practitioners, psychiatrists, and psychologists. Another exception was in the basic research category.

Discussion

Trauma care is largely dependent on the organization of services as well as on highly resource-dependent variables, including the availability of specialists and access to essential supplies.[15] The number of orthopaedic and traumatology specialists per capita ranges substantially across income groups, with the number of surgeons providing care for musculoskeletal injuries being estimated at 2.6 per one million inhabitants in LMICs and 58.8 per one million inhabitants in HICs.[8] Similarly, there are disparities in the equipment, materials, and supplies needed to support musculoskeletal trauma care across different regional economies that further impact injury

management, although the specific resources required for this care are not well documented.[16,17] Higashi et al. estimated that in LMICs, 21% of the morbidity and mortality due to injuries is potentially modifiable with the establishment of basic trauma care provisions,[18] underscoring the importance of identifying the most high-yield resources for musculoskeletal care.

In the present study, consensus was reached on 71 items that were considered "most essential" by the expert panel across all income groups, suggesting that these are widely regarded as the most basic of required resources. Significant differences were observed in 16 resources, all related to general trauma management and not musculoskeletal injury care, further demonstrating consensus on essential musculoskeletal resources across regions. The most essential resources that were identified should be considered for inclusion in guidelines. Many LMICs often do not have the supplies and equipment recommended in trauma care protocols. Therefore, many LMIC providers only refer to guidelines for needs assessments, advocacy, and policy development purposes, with a minority implementing these recommendations.[10,19] This suggests that the recommended use of locally available resources is critical for effective guidelines.[20–22] The differences in ratings by surgeons in the present study were likely reflective of the availability of the current resources in their respective countries. Resources such as air medical services and internet access, both ranked as highly important among surgeons in HICs and UMICs, were rated substantially lower by surgeons in LMICs. Similarly, more-advanced technological resources that are more accessible in resource-rich countries, such as computed tomography (CT) suites and 24/7 (always available) angiography suites, were also ranked differently by surgeons across income groups. Among the list of most essential resources, surgeons from HICs ranked specialized medical personnel higher than those from LMICs and UMICs. Notably, surgeons from LMICs and UMICs rated primary healthcare personnel as being more important than did those from HICs, perhaps indicating primary care providers play a more substantial role in resource-limited settings. These findings support the importance of prioritizing locally available equipment and services for the development of effective guidelines.[23,24]

In an effort to improve trauma care quality, the American College of Surgeons (ACS) Task Force of the Committee on Trauma developed a list of essential and desirable provisions considered to be important for trauma care (pre-hospital to post-hospital), with an emphasis on surgeons and patients in rural settings.[21] Subsequently, Mock et al., in collaboration with the World Health Organization, established the Essential Trauma Care (EsTC) Project in 2004, which recommended affordable supplies and equipment, specifically for LMICs.[6,22] The list of recommendations addressed general trauma surgical services, including basic resuscitation, airway management, and hemorrhage control. While the EsTC Project has made progress in implementing locally relevant recommendations across sites in LMICs,[6] it was focused on countries within a specific economic group and on general trauma care (rather than comprehensive musculoskeletal injury management). In 2018, Chan et al. conducted a Delphi study to develop recommendations for an essential list of trauma and orthopaedic equipment for non-operative, specialist, and tertiary providers across LMICs in Africa.[24] The current study expands on that work and includes three phases of care, identifying additional resource categories (i.e., personnel, education, policies, protocols).

The present study had several potential limitations. Although more than 300 unique resources were reported by the expert panel, it is highly likely that there were additional items –

particularly, more basic supplies, such as sutures – that were not identified in the study. In addition, for the purposes of identifying a list of resources that were considered to be "most important," a post hoc modification was made with a more stringent set of criteria. By doing so, some key resources may not have been identified in the "most essential" category. These essential resources could be considered more prominently, but not exclusively, for recommended guidelines. Furthermore, as the survey was designed in the English language, this may have limited the participants' responses. Additionally, while more than 70% of the respondents had greater than 10 years of experience, the remainder had fewer years of experience and may not have had the same level of knowledge as their counterparts. Finally, although employing a larger sample size than most Delphi studies,[13] the present study sought to have sufficiently broad geographical and economical representation for comparison between income groups.[6] The selection of one surgeon-expert per country provided for this greater overview; however, a single surgeon would not be representative of an entire country or region, within which substantial variations in socioeconomic conditions may exist. Further investigation is therefore necessary to evaluate and validate resource criteria that are unique to specific regions; the findings from this study could be used as a basis for those investigations.

In summary, resource availability is critical for the successful development of trauma systems and the delivery of musculoskeletal trauma care. In the present study, survey respondents from LMICs, UMICs, and HICs achieved agreement on a core list of essential musculoskeletal trauma care resources. The results of this study underscore the need to prioritize resources that are locally available in any given setting rather than those that are not accessible. This study represents a first step toward establishing international consensus. The information can be used to develop effective guidelines and policies, create best-practice treatment standards, and advocate for necessary resources worldwide.

References

1. Krug EG, Sharma GK, Lozano R. The Global Burden of Injuries. *Am J Public Health*. 2000;90(4):523-526.
2. Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJL. Global and Regional Burden of Disease and Risk Factors, 2001: Systematic Analysis of Population Health Data. *The Lancet*.
3. World Health Organization. Injuries and Violence: The Facts. Published online 2014:1-20. https://apps.who.int/iris/bitstream/handle/10665/149798/9789241508018_eng.pdf
4. Haagsma JA, Graetz N, Bollinger I, Naghavi M, Higashi H, Mullany EC, et al. *Inj Prev*. 2016;(22):3-18. doi:10.1136/injuryprev-2015-041616
5. Mock C, Joshipura M, Goosen J, Lormand JD, Maier R. Strengthening Trauma Systems Globally: The Essential Trauma Care Project. *J Trauma*. 2005;59:1243-1246.
6. Mock C, Nguyen S, Quansah R, Arreola-Risa C, Viradia R, Joshipura M. Evaluation of Trauma Care Capabilities in Four Countries Using the WHO-IATSIC Guidelines for Essential Trauma Care. *World J Surg*. 2006;30:946-956.
7. Nathens A, Jurkovich G, Rivara F, Maier RV. Effectiveness of State Trauma Systems in Reducing Injury-Related Mortality: A National Evaluation. *J Trauma*. 2000;48(1):25-30.
8. Miclau T, Hoogervorst P, Shearer DW, El Naga A, Working ZM, Martin C, Pesantez R, Huttl T, Kojima KE, Schutz M, International Orthopaedic Trauma Study Consortium. Current Status of Musculoskeletal Trauma Care Systems Worldwide. *J Orthop Trauma*. 2018;32(10):S64-70.
9. Dijkink S, Nederpelt CJ, Krijnen P, Velmahos GC, Schipper IB. Trauma Systems Around the World: A Systematic Overview. *J Trauma Acute Care Surg*. 2017;83:917.
10. LaGrone L, Riggle K, Joshipura M, Quanash R, Reynolds T, Sherr K, Mock C. Uptake of the World Health Organization's Trauma Care Guidelines: A Systematic Review. *Bull World Health Organ*. 2016;94:585-598.
11. Jones J, Hunter D. Consensus Methods for Medical and Health Services. *BMJ*. 1995;311(7001):376-380.
12. Hasson F, Keeney S, McKenna H. Research Guidelines for the Delphi Survey Technique. *J Adv Nurs*. 2000;32(4):1008-1015.
13. Diamond IR, Grant RC, Feldman BM, Pencharz PB, Ling SC, Moore AM, Wales PW. Defining Consensus: A Systematic Review Recommends Methodologic Criteria for Reporting of Delphi Studies. *J Clin Epidemiol*. 2014;67:401-409.
14. The World Bank. Data: Country and Lending Groups 2021. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
15. Global Status Report on Noncommunicable Diseases 2010: Description of the Global Burden of NCDs, Their Risk Factors and Determinants. Published online 2011.
16. Mock CN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Orthop Relat Res*. 2008;466(10):2306-2316.
17. Gosselin RA, Spiegel DA, Coughlin RR, Zirkle LG. Injuries: The Neglected Burden in Developing Countries. *Bull World Health Organ*. 2009;87(4):246-247.
18. Higashi H, Barendregt JJ, Kassenbaum NJ, Weiser TG, Bickler SW, Vos T. Burden of Injuries Avertable by a Basic Surgical Package in Low-and Middle-Income Regions: A Systematic Analysis from the Global Burden of Disease 2010 Study. *World J Surg*. 2015;39:1-9.

19. Choi J, Carlos G, Nassar AK, Knowlton LM, Spain DA. The Impact of Trauma Systems on Patient Outcomes. *Curr Probl Surg*. 2021;58:1-21.
20. Turner J, Duffy S. Orthopaedic and Trauma Care in Low-Resource Settings: The Burden and Its Challenges. *Int Orthop*. 2022;46:143-152.
21. American College of Surgeons. Resources for Optimal Care of the Injured Patient: An Update. *ACS Bull*. 1990;75(9):20-29.
22. Mock C, Joshipura M, Goosen J, Maier R. Overview of the Essential Trauma Care Project. *Wolrd J Surg*. 2006;30(6):919-929.
23. Mock C, Lormand JD, Goosen J, Joshipura M, Peden M. Guidelines for Essential Trauma Care. Published online 2004.
24. Chan Y, Banza L, Martin C, Harrison WJ. Essential Fracture and Orthopaedic Equipment Lists in Low Resource Settings: Consensus Derived by Survey of Experts in Africa. *BMJ Open*. 2018;8:e023473.

Figure 1. Flow of survey administration and respondents

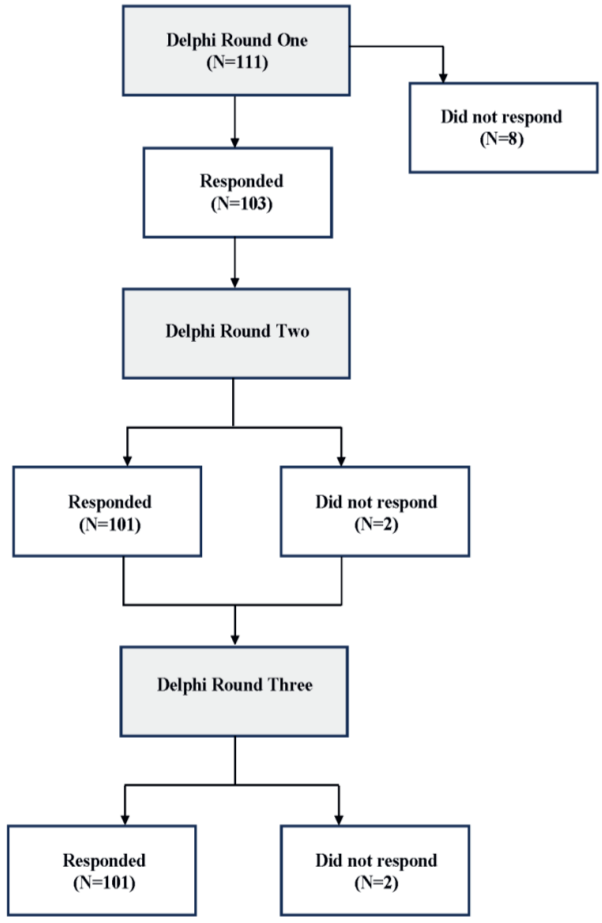


Figure 2. World map representing respondents' countries of origin

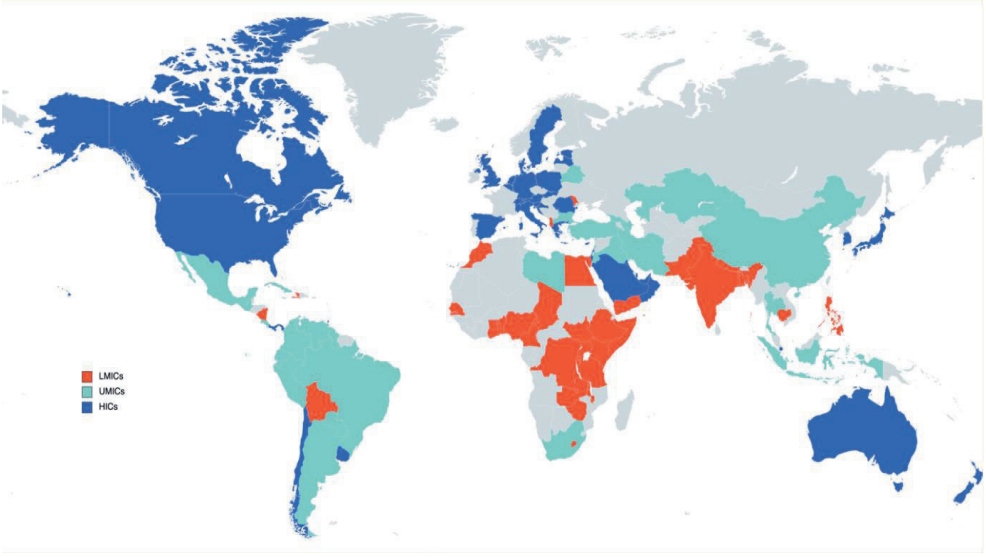


Table 1. Demographic data of surgeon respondents

Characteristic	**N (%)**
Total	*103 (100)*
Training	
Orthopaedic surgeon	93 (90.3)
Fellow (undergoing orthopaedic trauma specialty training)	7 (6.8)
Other	3 (2.9)
Years in practice	
0-5	18 (17.5)
6-10	12 (11.7)
11-15	15 (14.5)
16-20	11 (10.7)
>20	47 (45.6)
Fellowship in orthopaedic trauma	
Yes	80 (77.7)
No	23 (22.3)
Practice setting[+]	
Academic	64 (62.1)
Private Clinic	47 (45.6)
Public Hospital	31 (30.1)
Other	3 (2.9)
Country income group	
Low-Income & Lower-Middle-Income (LMICs)	36 (35)
Upper-Middle-Income (UMICs)	31 (30)
High-Income (HICs)	36 (35)

[+]Multiple responses were selected

Table 2. Most essential resources identified across income groups (LMICs, UMICs, and HICs)*

Pre-Hospital Phase					
	Overall Mean	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Ancillary Services					
Ambulance services	1.53	1.53	1.73	1.37	0.30
Emergency medical response system	1.71	1.80	1.53	1.77	0.35
Personnel					
Quick response team	1.97	2.00	2.23	1.71	0.28
Supplies					
IV fluids	1.47	1.51	1.47	1.43	0.96
Surgical gloves	1.49	1.69	1.50	1.29	0.25
Cervical collar	1.52	1.54	1.47	1.54	0.57
Resuscitation kit/airway management	1.53	1.77	1.73	1.20	0.05
Pulse oximeter	1.56	1.77	1.73	1.20	0.05
Face mask	1.61	1.66	1.77	1.42	0.69
Life support equipment	1.67	1.60	1.93	1.51	0.30
Spine board	1.75	1.83	1.90	1.54	0.73
Basic dressings	1.82	1.94	1.77	1.74	0.74
Antiseptics/iodine	1.89	1.80	1.97	1.91	0.90
Basic immobilization systems	1.95	1.80	2.13	1.94	0.88
In-Hospital Phase					
	Overall Mean	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Training					
Training OR trauma surgeon	1.77	1.69	1.60	1.40	0.70
Training OR orthopaedic surgeon	1.83	1.61	1.60	1.48	0.48
Training ER staff/nursing	1.85	1.78	1.83	1.51	0.59
Training ER physician	1.86	1.67	1.80	1.54	0.61
Training OR anesthesia	1.93	1.78	1.90	1.42	0.14
Education					
Advanced Trauma Life Support (ATLS)	1.76	1.63	1.77	1.34	0.35
Continuous Medical Education (CME)	1.85	1.64	2.13	1.54	0.12
Personnel					
Anesthesiologist	1.42	1.47	1.33	1.08	0.14
Nursing	1.75	1.96	1.67	1.54	0.50
Radiologist	1.85	1.91	1.83	1.63	0.66
ER physician	1.85	1.89	1.97	1.77	0.23
Orthopaedic trauma surgeon	1.88	1.50	1.83	1.43	0.23
Neurosurgeon	1.93	1.93	2.00	1.80	0.45
Policies					
24/7 in-house anesthesiologist	1.80	1.72	1.37	1.11	0.03
24/7 in-house trauma surgeon	1.98	1.97	2.03	1.63	0.43
Protocols					
Trauma imaging protocol	1.80	1.83	2.10	1.34	0.14
Pre-operative anesthesia assessment	1.88	2.14	2.20	1.74	0.85
Trauma management protocol	1.90	1.75	2.07	1.43	0.43
Trauma triage protocol	1.95	1.64	2.20	1.37	0.15

Musculoskeletal trauma management protocol	1.98	1.80	2.10	1.60	0.64
Pelvic trauma management protocol	1.98	1.69	2.07	1.48	0.48
Operating room surgery triage – urgent cases	2.00	1.97	2.20	1.37	0.13
Multidisciplinary team management	2.00	1.86	2.13	1.51	0.43
Supplies					
Radiographs	1.31	1.69	1.23	1.08	0.02
Intubation supplies	1.45	1.47	1.47	1.0	0.006†
OR equipment	1.45	1.56	1.53	1.03	0.02
Autoclave sterilization	1.46	1.53	1.53	1.14	0.15
Surgical gloves	1.46	1.44	1.37	1.08	0.06
Antibiotics	1.52	1.56	1.50	1.23	0.31
Power equipment	1.56	1.56	1.83	1.08	0.06
Internal fixation - nails	1.56	1.69	1.73	1.17	0.05
CT	1.58	2.03	1.40	1.08	0.003†
External fixators	1.58	1.72	1.70	1.08	0.08
Analgesia	1.59	1.56	1.70	1.14	0.01†
Dressings	1.60	1.53	1.57	1.17	0.02
Ultrasound	1.63	1.78	1.77	1.57	0.35
Ventilator	1.65	1.69	1.70	1.03	0.006†
Internal fixation - plates	1.69	1.89	1.63	1.14	0.24
Splint material	1.77	1.53	1.77	1.34	0.14
Anticoagulants	1.82	2.08	1.80	1.48	0.13
Traction table	1.86	1.80	2.03	1.23	0.05
Radiolucent fracture table	1.95	1.78	2.17	1.23	0.04
Emergency Department					
Procedure Room	1.94	1.86	2.23	1.71	0.70
Operating Room					
24/7 availability trauma	1.71	1.78	2.10	1.40	0.26
OR priority for emergency surgeries	1.74	1.80	1.80	1.17	0.14
Availability trauma	1.85	1.78	2.00	1.49	0.63
24/7 dedicated availability for musculoskeletal trauma	1.95	1.80	2.20	1.49	0.34
Infrastructure					
Blood bank	1.60	1.81	1.67	1.17	0.13
Clinical laboratories	1.66	1.81	1.87	1.40	0.35
Reliable power supply	1.68	1.67	1.83	1.23	0.16
Intensive Care Unit - general	1.80	1.75	1.78	1.08	0.01†
Intensive Care Unit – trauma/surgery	1.90	1.94	1.87	1.83	0.87
Post-Hospital Phase					
	Overall Mean	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Personnel					
Orthopaedic surgeon	1.77	1.69	1.93	1.54	0.39
Supplies					
Radiographs	1.44	1.50	1.53	1.14	0.05
Analgesia	1.77	1.61	1.97	1.26	0.07
Antibiotics	1.81	1.64	1.80	1.66	0.58
Dressings	1.89	1.80	2.07	1.34	0.05

*Resources rated ≤2 with consensus by ≥75% of the group. IV= intravenous, OR= operating room, ER= emergency room, CT= commuted tomography
†Significance level = p≤0.0167

Table 3. Statistically significant differences in ratings between income groups (LMICs, UMICs, HICs)*

Pre-Hospital Phase				
Resource	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Ancillary Services				
Air medical airplane/helicopter services	5.33	3.83	3.09	<0.001
Infrastructure				
Internet access	2.60	2.47	1.51	0.01
In-Hospital Phase				
Resource	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Personnel				
Research assistant	3.05	4.13	4.34	0.01
General practitioner	3.22	3.70	4.60	0.008
Psychiatrist	3.61	4.67	4.77	0.01
Psychologist	3.44	4.93	4.83	0.001
Research				
Basic research	2.72	4.13	4.23	0.003
Supplies				
Intubation supplies	1.47	1.47	1.00	0.006
CT	2.03	1.40	1.08	0.003
Analgesia	1.56	1.70	1.14	0.01
Ventilator	1.69	1.70	1.03	0.006
Skin grafting equipment	2.0	3.07	1.91	0.004
Infrastructure				
Intensive care unit - general	1.75	1.78	1.08	0.01
CT imaging proximity to ED	2.40	2.27	1.37	0.01
24/7 angiography suite	3.42	3.03	2.00	0.002
Post-Hospital Phase				
Resource	**LMIC Mean**	**UMIC Mean**	**HIC Mean**	**P Value**
Community Education				
Short-term housing	3.67	4.63	3.40	0.01

*Out of the total of 308 resources identified. CT= commuted tomography, ED= emergency department

Acknowledgments

†Delphi Study Group (Corporate Authors)

Anani G. Abalo, MD (Service de Traumatologie Orthopédie, CHU Sylvanus Olympio, Faculté des Sciences de la Santé, Universite de Lomé, Lomé, Togo); Ephrem Adem, MD (Department of Orthopaedics and Traumatology, Hawassa University, Awasa, Ethiopia); Dino Aguilar, MD (Centro Ortopedia, Hospital Vivian Pellas, Managua, Nicaragua); Waleed A. Al-Saadan, MD (Joint Replacement Center, Medical City Teaching Complex of Baghdad, Baghdad, Iraq); Mohammed Alsaifi, MD (Department of Orthopedic and Trauma 21 September University for Medicine and Applied Sciences, Sana'a, Yemen); Rafael Amadei, MD (Trauma Unit, Orthopaedics and Traumatology Service, Cuena Alta Cañuela Hospital); Theerachai Apivatthakakul, MD (Department of Orthopaedics, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand); Mapuor M.M. Areu, MD (Department of Orthopaedics and Trauma, University of Juba, Juba, South Sudan); Federico Bove, MD (Department of Orthopaedics and Traumatology, ASST Grande Ospedale Metropolitano Niguarda, Milan, Italy); Rastislav Burda, MD (Department of Trauma Surgery, Pavol Jozef Šafárik University in Košice, Faculty of Medicine Rastislavova 43, Košice, Slovakia, Department of Trauma Surgery, Louis Pasteur University Hospital, Rastislavova 43, Košice, Slovakia); Alex M. Butera, MD (Department of Orthopedic Surgery, Rwanda Military Hospital, Kigali, Rwanda); Linda C. Chokotho, MD (Academy of Medical Sciences, Malawi University of Science and Technology, Blantyre, Malawi); Alvaro Cordero, MD (Department of Orthopedic Surgery, Hospital México, CCSS, San José, Costa Rica); Adel Ebrahimpour, MD (Department of Orthopedic Surgery, Clinical Research Development Unit of Shohada-e Tajrish Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran); John Ekure, MD (Kumi Orthopaedic Center, Kumi, Uganda); Igor A. Escalante E., MD (Orthopaedic Surgery at Hospital Universitario de Caracas, Universidad Central de Venezuela); Osama Farouk, MD (Department of Orthopaedic Surgery, Faculty of Medicine, Assiut University, Asyut, Egypt); Christos Garnavos, MD, PhD, FIOTA (Department of Orthopaedic and Trauma Surgery, "Evangelismos" General Hospital of Athens, Athens, Greece); Mario Garuz, MD (Department of Orthopaedics, Hospital Santo Tomas, Panama City, Panama); Florian Gebhard, MD, PhD (Ulm University Medical Center, Department of Orthopaedic Trauma, Ulm, Germany); Andres Gelink, MD (Department of Orthopaedic Surgery, Circulo Catolico de Obreros del Uruguay, Montevideo, Uruguay); Torsten G. Gerich, MD (Centre Hospitalier de Luxembourg, Department of Orthopaedic Trauma, Luxembourg City, Luxembourg); Wojciech Michał Glinkowski MD, PhD (Center of Excellence "TeleOrto", Telediagnostics and Treatment of Disorders and Injuries of the Locomotor System, Medical University of Warsaw, Warsaw, Poland); Paata Gudushauri, MD, PhD (Sports Public University, Aversi Central Clinic, Tbilisi, Georgia); Enrique Guerado, MD (Department of Orthopaedic Surgery and Traumatology, Hospital Universitario Costa del Sol, University of Malaga, Malaga, Spain); Billy T. Haonga, MD (Department of Orthopaedic Surgery, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania); Yazan J. Hattar, MD (Specialty Hospital, Amman, Jordan); Zekeriya Ugur Isiklar, MD (Orthopaedist, Istanbul, Turkey); Rishi Jagdeo MD, MB, BS, MSc, MBA, LLM (Private Practice, San Fernando, Trinidad and Tobago); Fareed H.Y. Kagda, MD, FRCS (Department of Orthopaedic Surgery, Ng Teng Fong General Hospital, National University Health System, Kent Ridge, Singapore); Radko Komadina, MD (Medical Faculty Ljubljana, Ljubljana, Slovenia); Arjun Lamichhane, MD, MS (Department of Orthopaedics, Tribhuvan University Teaching Hospital, Maharajgunj Medical Campus Institute of Medicine, Kathmandu, Nepal); Jean Pierre F. Leung, MD

(Department of Orthopaedics, Notre Dame de Chartres Hospital, Baguio City, Philippines); Florent Anicet Lekina, MD (Association Camerounaise pour l'Ostéosynthèse, Cameroon); Esther M.M. Van Lieshout, PhD, MSc (Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands); Biser Makelov, MD, PhD (Department of Orthopaedic Surgery, University Hospital for Active Treatment "Prof Dr S. Kirkovitch" Stara Zagora, Sofia, Bulgaria); Kebba S. Marenah, MD (Department of Trauma and Orthopaedics, Edward Francis-Small Teaching Hospital, Banjul, The Gambia); Konstantinos Michail, MD, MSc (Department of Orthopaedic Surgery, Papageorgiou University Hospital of Thessaloniki, Greece); Anna N. Miller, MD (Washington University in St. Louis, Department of Orthopaedic Surgery, St. Louis, Missouri, United States of America); Sayid Omar Mohamed, MD (Department of Orthopaedic Surgery, Jazeera University Hospital, Mogadishu, Somalia); Younes El Moudni, MD (Department of Trauma and Orthopedic Surgery, Ibn Rochd University Hospital, Casablanca, Morocco); Walid Mugla, MD (Orthopaedic Department, Groote Schuur Hospital, Cape Town, South Africa); Josep Maria Muñoz-Vives, MD (Departament of Orthopaedic Surgery, Hospital Nostra Senyora de Meritxell, Les Escaldes, Andorra); James Munthali, MD (Orthopaedic Unit, Department of Surgery, University of Zambia, Lusaka, Zambia); Thomas Nau, MD (King's College Hospital London Dubai, Mohammed Bin Rashid University of Medicine and Health Sciences, Dubai, United Arab Emirates); Pierre Navarre, MD, FRACS (Department of Orthopaedic Surgery, Southland Hospital, New Zealand, University of Otago, Otago, New Zealand); Horacio Tabares Neyra, MD (Cirugia del Centro de Investigaciones en Longevidad, Envejecimiento y Salud, CITED, Havana, Cuba); Reuben K.S. Ngissa, MD, MBChB (UG), FGCS (Ortho) (Department of Surgery, Trauma and Orthopaedic Unit, Greater Accra Regional Hospital, Accra, Ghana); Tomoyuki Noda, MD, PhD (Department of Orthopaedic Surgery and Traumatology, Kawasaki Medical University General Hospital, Okayama, Japan); Hermann Oberli, MD (Department of Orthopaedic Surgery, National Referral Hospital Honiara, Guadalcanal, Solomon Islands); Gerald Oguzie, MD (Department of Orthopedic Surgery, Federal University Teaching Hospital, Owerri, Nigeria); Elchin Orujov, MD (Azerbaijan Medical University, Department of Orthopaedics and Traumatology, Baku, Azerbaijan); Luis G. Padilla, MD (Department of Orthoapedic Surgery, Puerta de Hierro Hospital, Zapopan, Jalisco, Mexico); Hans-Christoph Pape, MD (Department of Trauma, University of Zurich, Zurich, Switzerland); Col. Narayan Ramachandran, MD, MS, MSc, PCLC (Support and Inspire Consulting Services, Muscat, Oman, Armed Forces Hospital, Salalah, Oman); Victor A. de Ridder, MD, PhD (Department of Trauma, University Medical Center, Utrecht, The Netherlands); Iván Salce, MD (Departamento de Traumatologia y Ortopedia, Clínica Delgado AUNA, Lima, Perú); Ulf Schmidt, MD (Spinal Cord Injury Center, Werner Wicker Clinic Bad Wildungen, Bad Wildungen, Germany); Emil H. Schemitsch, MD (Department of Surgery, University of Western Ontario, London, ON, Canada); Daniele Sciuto, MD (Department of Orthopaedics and Trauma, Samburu County Referral Hospital, Samburu, Kenya); Julio Segovia, MD (Department of Orthopedic Surgery, Grupo San Roque Hospitals, Asuncion, Paraguay); Edvin Selmani MD, PhD (University of Medicine Tirana, University Trauma Hospital Tirana, Tirana, Albania); Fandebnet Siniki, MD (Chef de Service de Chirurgie Orthopédique et Traumatologique du Centre Hospitalier Universitaire, Ndjamena, Chad); Alexandre Sitnik, MD, PhD (Adult Trauma Department, Belarus Republic Scientific and Practical Center for Traumatology and Orthopedics, Minsk, Belarus); Andrey Smirnov, MD (Orthopaedic Centre, East-Tallinn Central Hospital, Tallinn, Estonia); Huot Socheat, MD (Battambang Provincial Hospital, Battambang, Cambodia); Darko Talevski, MD (Department of

Orthopaedics and Trauma Surgery, General City Hospital "September 8th", Skopje, Republic of North Macedonia); Igors Terjajevs, MD (Department of Bone Infection and Reconstructive Surgery, Hospital of Traumatology and Orthopaedics, Riga, Latvia); Kighoma K. Vuhaka, MD (Department of Orthopaedics and Trauma, University of Goma, Tertiary HEAL Africa Hospital, Democratic Republic of the Congo); Yoram A. Weil, MD (Department of Orthopaedics, Hadassah Hebrew University Hospital, Jerusalem, Israel); Olof Wolf, MD, PhD (Department of Surgical Sciences, Department of Orthopaedics, Uppsala University, Uppsala, Sweden); Pierre M. Woolley, MD (Department of Orthopaedics, HUP La Paix University Hospital, Port-au-Prince, Haiti)

CHAPTER 7

7

Orthopaedic Trauma Research Priorities in Latin America: Developing Consensus through a Modified Delphi Approach

Roberts HJ[1], MacKechnie MC[1], Shearer DW[1], Segovia Altieri J[2], De la Huerta F[3], Rio MW[4], Sánchez Valenciano C[5], Miclau T[1] and the ACTUAR Study Group[†]

[1]University of California, San Francisco, San Francisco, CA, USA
[2]Instituto de Prevision Social, Servicio de Ortopaedia y Traumatología, Asunción, Paraguay
[3]Unidad de Ortopedia y Traumatología, Guadalajara, Mexico
[4] Ortopedia y Traumatología Clínica Zabala, Buenos Aires, Argentina
[5]Centro Medico de Caracas, Caracas, Venezuela

J Bone Joint Surg Am. 2021;103(24):2318-23

Abstract

Background: Despite a significant burden of musculoskeletal injury, orthopedic trauma studies in Latin America are lacking. This study aimed to identify research priorities among orthopedic trauma surgeons in Latin America.

Materials and Methods: Research questions were solicited from members of the Asociación de Cirujanos Traumatólogos de las Américas. Participants rated questions by importance from 1 to 9. All questions were redistributed with aggregate rating, and participants rerated questions with knowledge of group responses.

Results: Seventy-eight participants completed the first survey and were included in subsequent surveys. The mean age was 51.8 years, and most participants were male (92%), had completed an orthopedic trauma fellowship (60.3%), and participated in research (80.8%). Seventeen countries were represented; five respondents were from a high-income country, 67 from an upper middle-income country, and six from a lower middle-income country. Sixty-five questions were identified. Six questions were rated from 1 to 3 ("more important") by >70% of participants:

1. What is the optimal treatment protocol for elderly patients with hip fracture?
2. What is the most effective initial and definitive management of musculoskeletal injury, including timing and surgical strategy, for the polytraumatized patient?
3. What is the ideal state of open fracture treatment, including timeliness and method of antibiotics, debridement, surgical fixation, and closure or coverage, at each hospital level in the health-care system?
4. What patient and fracture characteristics predict infection after musculoskeletal injury?
5. What is the current state of treatment for fracture-related infection, including timeliness and method of antibiotics and surgical intervention, at each hospital level in the health-care system?
6. What is the optimal protocol for temporary management for the hemodynamically unstable patient with a pelvic or acetabular fracture?

Conclusion: This modified Delphi study of orthopedic trauma surgeons in Latin America identified geriatric hip fractures, polytrauma, open fractures, musculoskeletal infection, and pelvic and acetabular fractures as top research priorities. This information is important for resource allocation and goal setting for orthopedic trauma in the region.

Level of Evidence: V

Introduction

Building health research capacity is necessary to help guide future treatment on critical clinical questions.[1] Over the last two decades, developing and advancing health research has become an increasingly recognized global health priority, particularly for musculoskeletal injury care. Traumatic injury is a leading cause of mortality and disability worldwide, with an estimated 1.2 million deaths and 50 million non-fatal injuries every year, many of which are due to musculoskeletal trauma.[2–5] Low-and middle-income countries (LMICs), including those in Latin America, are disproportionately affected by this burden, with the highest number of deaths per capita compared to higher-income countries.[5]

Despite this burden, studies of orthopedic trauma in Latin America are lacking. Research from Latin America lags behind the rest of the world after adjusting for gross domestic product (GDP) and population,[6] and, between 1988 and 2013, only 1% of orthopedic articles came from a Latin American country.[7] Even among LMICs, Latin America is underrepresented, with only 3.1% of orthopedic trauma studies originating from Latin America.[8] While burden of road traffic injuries is higher than in North America, fewer randomized controlled trials in orthopedic trauma – and particularly collaborative multi-center trials – have originated from Latin America compared with North America.[9] Factors such as GDP, lack of health research funding, and lack of investigational infrastructure limit the expansion of knowledge in this area.[6,10,11] In recognition of this limitation, leading international health agencies such as the World Health Organization and the Pan American Health Organization have urged the development of research agendas. While the development of investigative collaborative networks and clinical research courses in Latin America have increased health research to some extent, knowledge gaps remain.[10,12–14]

This lack of population-specific research limits countries' abilities to improve care for patients with musculoskeletal injuries, advocate for necessary clinical resources, and inform research and policy priorities. An important first step in improving musculoskeletal research is to determine research priorities in order to set an agenda for future studies. The aim of this study was to use a modified Delphi methodology to identify research priorities of orthopedic trauma surgeons in Latin America.

Materials and Methods

The Delphi process is a method of determining consensus among a group of experts.[15,16] Named after the oracle at Delphi, this method was originally developed by the RAND Corporation for technological predictions but has since been widely used in health research. The process involves an iterative series of surveys with the intent of turning opinion into consensus, whereby respondents have the opportunity to modify their responses based on the collective group opinion. The Delphi process and its modifications have been used in multiple studies in the field of orthopaedics.[17–20]

A modified Delphi process was conducted between May and October 2020 to identify research priorities among orthopedic trauma surgeons in Latin America. The Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR) network was utilized for this study. ACTUAR was developed in 2017 by 60 orthopedic surgeon leaders representing 20 countries throughout Latin America, and a primary goal of the association is to support collaborative research work. All

ACTUAR members who were practicing orthopedic surgeons and treated orthopedic trauma conditions were invited to participate.

For each stage of the survey, English and Spanish translation followed by back-translation was performed by bilingual members of the study team. Discrepancies were resolved by consensus. While the survey was not translated into Portuguese, all participants were fluent in English, Spanish, or both.

Scoping survey: A scoping survey with the purpose of identifying important research questions in orthopedic trauma was distributed to ACTUAR members. Demographic information was collected, including country of practice, years of practice, practice environment, subspecialty training, amount of practice dedicated to orthopedic trauma, and research participation. Participants were asked to submit important clinical questions in orthopaedic trauma in their clinical setting that should be addressed through research. There was no limit on the number of questions that a participant could submit, and multiple questions were encouraged. The scoping survey was open for 14 weeks in total. After the scoping survey was closed, the proposed research questions were compiled and grouped according to topic areas. Free-text questions were reviewed by an expert panel of orthopedic trauma surgeons, and duplicate or overlapping questions were merged into a single question.

Delphi Round 1: An electronic survey consisting of the compiled research questions was distributed to members of ACTUAR who participated in the scoping survey. Members were asked to review each of the questions and rate them on a 9-point Likert scale based on the importance of each question. Scores of 1 to 3 were considered "more important", scores of 4 to 6 were considered "moderately important", and scores of 7 to 9 were considered "less important". The survey was available for completion for three weeks in total. Reminders were sent by e-mail one week before the survey closed. Respondents were invited to submit additional questions and to suggest refinements to the existing questions.

Delphi Round 1.5: Additional or modified questions that were generated from the prior round were sent to members who participated in the scoping survey for rating on the 9-point Likert scale.

Delphi Round 2: The compiled list of questions that had been rated was distributed again to all members who participated in the scoping survey, in order of rating from highest to lowest importance. Included in the Delphi Round 2 survey was a graphic display in the form of a histogram indicating the participants' responses in the prior surveys as well as the average rating. Participants were then invited to score questions again with knowledge of the group responses.

Analysis and Ranking: The research questions scored in Delphi Round 2 were ranked on the basis of the overall mean score per question. Questions that were rated between 1 and 3 by >70% of respondents were identified. Analyses were performed with use of Stata 13 software (StataCorp).

Source of Funding
This study was supported by funding from the Wyss Medical Foundation.

Results

The scoping survey was sent to 165 ACTUAR members, of whom 78 completed the survey. Of these 78 participants, 58 completed the Delphi Round 1 survey, 58 completed the Delphi Round 1.5 survey, and 60 completed the Delphi Round 2 survey (Figure 1). Fifty-three participants completed all surveys.

Demographic data of the 78 participants is listed in Table 1. Most participants were male (92%) and had been in practice for >15 years (66.7%), and mean age was 51.8 years. Almost all participants practiced in an urban setting (98.7%). More than half of the respondents had completed an orthopedic trauma fellowship (60.3%), three-quarters reported that orthopedic trauma made up >50% of their practice, and the majority participated in research (80.8%). With use of the World Bank 2020 to 2021 definition of country income levels, five respondents were from a high-income country, 67 were from an upper middle-income country, and six were from a lower middle-income country (Table 2).

A total of 36 unique research questions were identified from the scoping survey. An additional 29 questions were identified as either new or modified questions after the Delphi Round 1 survey. All research questions in order of final mean rating as obtained on the Delphi Round 2 survey are listed in the Appendix.

Of the 65 unique research questions, 41 had a mean rating of ≤3 ("more important"). Six questions received a score of 1 to 3 by >70% of participants, a threshold previously used to define consensus:[21–23] 1) What is the optimal treatment protocol (timing of surgery, co-management) for elderly patients with hip fracture? 2) What is the most effective initial and definitive management of musculoskeletal injury, including timing and surgical strategy, in the polytraumatized patient? 3) What is the ideal state of open fracture treatment, including timeliness and method of antibiotics, debridement, surgical fixation, and closure or coverage, at each hospital level in the health-care system (primary, secondary, tertiary)? 4) What patient and fracture characteristics predict infection after musculoskeletal injury? 5) What is the current state of treatment for fracture-related infection, including timeliness and method of antibiotics and surgical intervention, at each hospital level in the health-care system (primary, secondary, tertiary)? 6) What is the optimal protocol for temporary management for the hemodynamically unstable patient with a pelvic or acetabular fracture? (70.5%)

Discussion

This modified Delphi study, involving 78 participants from 17 countries in Latin America, clarifies research priorities among orthopedic trauma surgeons in this setting. The top six research questions, as listed above, focus on geriatric hip fracture, polytrauma, open fracture care, musculoskeletal infection, and care of patients with pelvic and acetabular fractures.

A previous study by Chomsky-Higgins et al. convened a focus group of 13 Latin American orthopedic surgeons who identified similar themes as important research questions for their setting, including fragility fractures, complication rates, and polytrauma protocols.[24] The similar findings in our study including a larger cohort of orthopaedic surgeons adds evidence that these

repeated themes are indeed priorities among this group. The Chomsky-Higgins study additionally suggested solutions to barriers to research, including multi-center studies, collaborations with institutions with established access to funding and journals, and modifying research questions to avoid challenges with patient follow-up. The ACTUAR network is well positioned to address these barriers because of its collaborative nature spanning across a variety of resource levels and the network's prior research experience.

Geriatric hip fractures pose a rising burden internationally. Annual cases are projected to exceed six million by 2050, with particular rise in LMICs in which life expectancy is most expected to increase.[25] For example, the population of Argentina is expected to increase by 28% between 2015 and 2050, and incidence of hip fractures are increasing by 1.4% per year.[26] In Mexico, hip fracture rates are suggested to be increasing at a rate of 1% per year.[27] With the rising burden of geriatric hip fractures in Latin America, and associated morbidity and mortality, it is not surprising that hip fracture management is important to orthopaedic trauma surgeons in the region.[28]

Both polytrauma and pelvic and acetabular fractures can be associated with high-energy injuries. A study from Southern Africa in which the Delphi methodology was used to identify learning priorities in the field of orthopaedic surgery for medical students, identified the multiply injured patient as a high priority.[29] The epidemiology of pelvic and acetabular fractures in Latin America is limited. A study from Mexico suggests that acetabular trauma is similar to that reported in other countries.[30] In LMICs, data regarding treatment and outcomes is particularly lacking. A study of orthopaedic surgeons in LMICs indicated hat only 21.3% of hospitals had access to pelvic angiography and 16% had access to prefabricated pelvic binders.[31] Additionally, >50% of surgeons caring for patients with these injuries had no formal training in pelvic and acetabular trauma. While a treatment algorithm of hemodynamic instability has been proposed,[32] these data support further study to determine optimal treatment in a variety of resource settings.

Open fractures, which represent a rising burden in Latin America due to road traffic injuries,[33] are associated with a substantial risk of musculoskeletal infection.[34] However, the burden of musculoskeletal infection in Latin America has not been well described. While the timeliness of antibiotic therapy is known to modify the risk of infection after open fracture,[34–36] INORMUS (International Orthopaedic Multicenter Study in Fracture Care), an international study of orthopedic trauma burden, identified Latin America as the region with the greatest proportion of patients with delays to care, with 88.7% of patients with open fractures experiencing delays.[37] Therefore, studies to describe current practices and define optimal treatment in Latin America have the potential to improve outcomes for patients with open fracture.

While the orthopedic trauma surgeons who participated in the present study were drawn from a network of those interested in research, these participants may not be representative of orthopedic trauma surgeons throughout Latin America as a whole. In particular, almost all of the respondents practice in an urban setting and therefore may not reflect the priorities of surgeons who practice in a rural setting. For example, these respondents may be biased toward research questions relevant to in-hospital care rather than pre-hospital care. In parts of Latin America, orthopaedic trauma surgeons may not be the primary providers of care for orthopaedic trauma conditions; general surgeons or trauma surgeons may provide care in some regions. However,

drawing participants from a research network has the advantage of selecting individuals who may have knowledge of gaps in the literature with respect to orthopedic trauma care in Latin America. Only 78 of 165 ACTUAR members participated in this survey, and the composition of the Delphi group may affect study outcomes, particularly because research priorities may vary across countries. The response rate in the present study is comparable with those in other Delphi studies conducted with similar methodology.[17,20] An additional limitation is that the vast majority of respondents were from upper middle-income countries, with only 14% from countries in other income levels. While this may be seen to limit the generalizability to upper middle-income countries, we believe that the results are meaningful as 17 countries in Latin America were represented. However, the concentration of respondents from one income level precluded the ability to identify an effect of income level on participant ratings.

Finally, successful implementation of studies to address the questions identified here requires careful and thoughtful design that incorporates the expertise of various stakeholders. Multi-center studies should consider the varied landscape of orthopaedic trauma throughout Latin American to identify nuances in conclusions. Health economists may assist in designing studies that address the economic aspects of injury and treatment as well as in designing programs that are ultimately feasible within local resource constraints. Consideration of pre-hospital care and access issues may improve the impact on orthopaedic trauma care.

In conclusion, this modified Delphi study of 78 orthopedic trauma surgeons in 17 countries in Latin America identified geriatric hip fracture, polytrauma, open fracture care, musculoskeletal infection, and care of patients with pelvic and acetabular fractures as top research priorities. This provides important information for resource allocation and goal-setting for orthopedic trauma in the region.

References

1. Perel P, Miranda JJ, Ortiz Z, Casas JP. Relation between the Global Burden of Disease and Randomized Clinical Trials Conducted in Latin America Published in the Five Leading Medical Journals. Clark J, ed. *PLoS ONE*. 2008;3(2):e1696. doi:10.1371/journal.pone.0001696
2. Holder Y, Peden M, Krug EG, et al. Injury Surveillance Guidelines. World Health Organization. Published online 2000.
3. Krug EG. Injury: A Leading Cause of the Global Burden of Disease. Geneva: World Health Organization. Published online 2000.
4. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med*. 2006;3(e442).
5. World Health Organization. Global status report on road safety: time for action. Geneva: World Health Organization. Published online 2009. Accessed December 19, 2020. https://apps.who.int/iris/bitstream/handle/10665/44122/9789241563840_eng.pdf;jsessionid=52695470F483BBEB25BFC5685C7FDC04?sequence=1.
6. Van Noorden R. The Impact Gap: South America by the Numbers. *Nature*. 2014;510:202-203.
7. Urrutia J, Zamora T, Prada C. The fifty most cited Latin-American articles in the orthopaedic literature. *Int Orthop*. 2014;38(8):1723-1729. doi:10.1007/s00264-013-2197-6
8. Challa S, Wu H-H, Cunningham BP, et al. Orthopaedic Trauma in the Developing World: Where Are the Gaps in Research and What Can Be Done? *J Orthop Trauma*. 2018;32:S43. doi:10.1097/BOT.0000000000001293
9. Moraes VY de, Belloti JC, Faloppa F, Bhandari M. Collaborative multicenter trials in Latin America: challenges and opportunities in orthopedic and trauma surgery. *Sao Paulo Med J*. 2013;131(3):187-192. doi:10.1590/1516-3180.2013.1313555
10. Becerra F, Cuervo LG. Health research in Latin America. *Lancet Lond Engl*. 2010;375(9709):120. doi:10.1016/S0140-6736(10)60045-1
11. Moloney, A. Latin America faces hurdles in health research. *The Lancet*. 2009;374:1053-1054. doi:https://doi.org/10.1016/S0140-6736(09)61688-3
12. Coronel E, Halstead D, Fregni F. Clinical research in Latin America: obstacles and opportunities. *Clin Investig*. 2011;1(7):911-913. doi:10.4155/cli.11.83
13. Miclau T, MacKechnie MC, Shearer DW, ACTUAR group. Asociación de Cirujanos Traumatólogos de las Américas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl 7:S8-S11. doi:10.1097/BOT.0000000000001302
14. Miclau TA, Chomsky-Higgins K, Ceballos A, et al. Building Surgical Research Capacity Globally: Efficacy of a Clinical Research Course for Surgeons in Low-Resource Settings. *Front Educ*. 2017;2(57). doi:https://doi.org/10.3389/feduc.2017.00057
15. Hasson F, Keeney S, McKenna H. Research guidelines for the Delphi survey technique: Delphi survey technique. *J Adv Nurs*. 2000;32(4):1008-1015. doi:10.1046/j.1365-2648.2000.t01-1-01567.x
16. Jones J, Hunter D. Qualitative Research: Consensus methods for medical and health services research. *BMJ*. 1995;311(7001):376-380. doi:10.1136/bmj.311.7001.376
17. Perry DC, Wright JG, Cooke S, et al. A consensus exercise identifying priorities for research into clinical effectiveness among children's orthopaedic surgeons in the United Kingdom. *Bone Jt J*. 2018;100-B(5):680-684. doi:10.1302/0301-620X.100B5.BJJ-2018-0051

18. Schneider P, Evaniew N, Rendon JS, et al. Moving forward through consensus: protocol for a modified Delphi approach to determine the top research priorities in the field of orthopaedic oncology. *BMJ Open*. 2016;6(5):e011780. doi:10.1136/bmjopen-2016-011780
19. Willett KM, Gray B, Moran CG, Giannoudis PV, Pallister I. Orthopaedic trauma research priority-setting exercise and development of a research network. *Injury*. 2010;41(7):763-767. doi:10.1016/j.injury.2010.03.026
20. Fernandez MA, Arnel L, Gould J, et al. Research priorities in fragility fractures of the lower limb and pelvis: a UK priority setting partnership with the James Lind Alliance. *BMJ Open*. 2018;8(10):e023301. doi:10.1136/bmjopen-2018-023301
21. Vogel C, Zwolinsky S, Griffiths C, Hobbs M, Henderson E, Wilkins E. A Delphi study to build consensus on the definition and use of big data in obesity research. *Int J Obes*. 2019;43(12):2573-2586. doi:10.1038/s41366-018-0313-9
22. Slade SC, Dionne CE, Underwood M, Buchbinder R. Standardised method for reporting exercise programmes: protocol for a modified Delphi study. *BMJ Open*. 2014;4(12):e006682. doi:10.1136/bmjopen-2014-006682
23. Diamond IR, Grant RC, Feldman BM, et al. Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *J Clin Epidemiol*. 2014;67(4):401-409. doi:10.1016/j.jclinepi.2013.12.002
24. Chomsky-Higgins K, Miclau TA, MacKechnie MC, et al. Barriers to Clinical Research in Latin America. *Front Public Health*. 2017;5:57. doi:10.3389/fpubh.2017.00057
25. Kannus P, Parkkari J, Sievänen H, Heinonen A, Vuori I, Järvinen M. Epidemiology of hip fractures. *Bone*. 1996;18(1 Suppl):57S-63S. doi:10.1016/8756-3282(95)00381-9
26. Ercolano MA, Drnovsek ML, Gauna A. Fractura de Cadera en los hospitales públicos de la Argentina. *Rev Argent Endocrinol Metab*. Published online 2012:3-11.
27. Johansson H, Clark P, Carlos F, Oden A, McCloskey EV, Kanis JA. Increasing age- and sex-specific rates of hip fracture in Mexico: a survey of the Mexican institute of social security. *Osteoporos Int*. 2011;22(8):2359-2364. doi:10.1007/s00198-010-1475-z
28. Rojas LGP, Hernández SQ, Ávila JMJ, et al. Hip fracture care—Latin America. *OTA Int*. 2020;3(1):e064. doi:10.1097/OI9.0000000000000064
29. Held MFG, Laubscher M, Graham SM, et al. Topics, Skills, and Cases for an Undergraduate Musculoskeletal Curriculum in Southern Africa: A Consensus from Local and International Experts. *J Bone Joint Surg Am*. 2020;102(3):e10. doi:10.2106/JBJS.19.00664
30. Zyman Corenstein J, Martínez Del Campo Sánchez A. [Acetabulum fractures in the Mexican population]. *Acta Ortop Mex*. 2018;32(5):251-256.
31. Whiting PS, Anderson DR, Galat DD, Zirkle LG, Lundy DW, Mir HR. State of Pelvic and Acetabular Surgery in the Developing World: A Global Survey of Orthopaedic Surgeons at Surgical Implant Generation Network (SIGN) Hospitals. *J Orthop Trauma*. 2017;31(7):e217-e223. doi:10.1097/BOT.0000000000000826
32. Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma: WSES classification and guidelines. *World J Emerg Surg WJES*. 2017;12. doi:10.1186/s13017-017-0117-6
33. Fraser B. Traffic accidents scar Latin America's roads. *Lancet Lond Engl*. 2005;366(9487):703-704. doi:10.1016/S0140-6736(05)67158-9
34. Patzakis MJ, Wilkins J. Factors influencing infection rate in open fracture wounds. *Clin Orthop*. 1989;(243):36-40.
35. Cross WW, Swiontkowski MF. Treatment Principles in the Management of Open Fractures. *Indian J Orthop*. 2008;42(4):377-386.

36. Giannoudis PV, Papakostidis C, Roberts C. A Review of the Management of Open Fractures of the Tibia and Femur. *J Bone Jt Surg*. 2006;88(3):281-289.
37. Pouramin P, Li CS, Busse JW, et al. Delays in hospital admissions in patients with fractures across 18 low-income and middle-income countries (INORMUS): a prospective observational study. *Lancet Glob Health*. 2020;8(5):e711-e720. doi:10.1016/S2214-109X(20)30067-X

Figure 1. Flow diagram of survey respondents

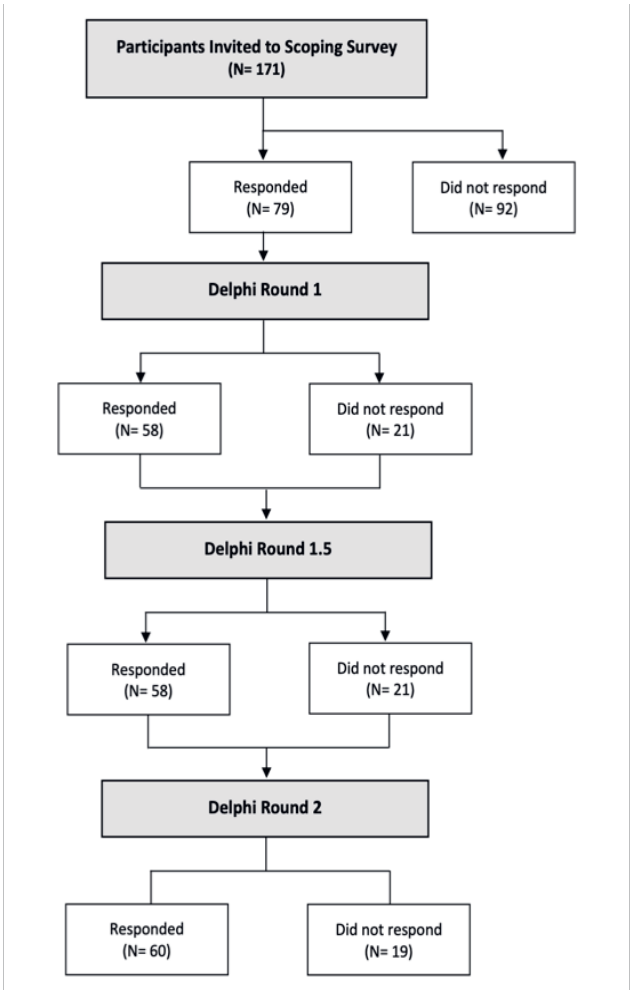


Table 1. Demographic data of survey respondents

Characteristics	
Age* (yr)	51.8 ± 9.7
Male (sex)†	72 (92.3)
Years in practice†	
0-5	3 (3.9)
6-10	11 (14.1)
11-15	12 (15.4)
16-20	14 (18.0)
>20	38 (48.7)
Completed orthopedic trauma fellowship†	47 (60.3)
Orthopedic trauma is >50% of practice†	59 (75.6)
Urban practice setting†	77 (98.7)
Practice setting†	
Academic practice	51 (35.4)
Private practice	56 (38.9)
Public hospital practice	35 (24.3)
Participate in research†	63 (80.8)

*The values are given as the mean and the standard deviation
†The values are given as the number of respondents, with the percentage in parenthesis

Table 2. Country of practice for invited and participant surgeons

Characteristic	**Number of surgeons invited to participate N=160* (%)**	**Number of surgey participants N=78 (%)**
Country of practice		
Argentina	7 (4.4)	7 (9)
Bolivia	5 (3.1)	-
Brazil	15 (9.4)	6 (7.7)
Chile	1 (0.6)	-
Colombia	46 (28.8)	19 (24.4)
Costa Rica	2 (1.3)	-
Cuba	3 (1.9)	2 (2.6)
Dominican Republic	1 (0.6)	1 (1.3)
Ecuador	1 (0.6)	1 (1.3)
El Salvador	4 (2.5)	2 (2.6)
Guatemala	5 (3.1)	1 (1.3)
Honduras	5 (3.1)	3 (3.8)
Mexico	38 (23.8)	24 (30.8)
Nicaragua	8 (5)	1 (1.3)
Panama	2 (1.3)	2 (2.6)
Paraguay	2 (1.3)	2 (2.6)
Peru	2 (1.3)	2 (2.6)
Puerto Rico	2 (1.3)	1 (1.3)
Uruguay	6 (3.8)	2 (2.6)
Venezuela	5 (3.1)	2 (2.6)

*Data not reported for one respondent

Acknowledgements

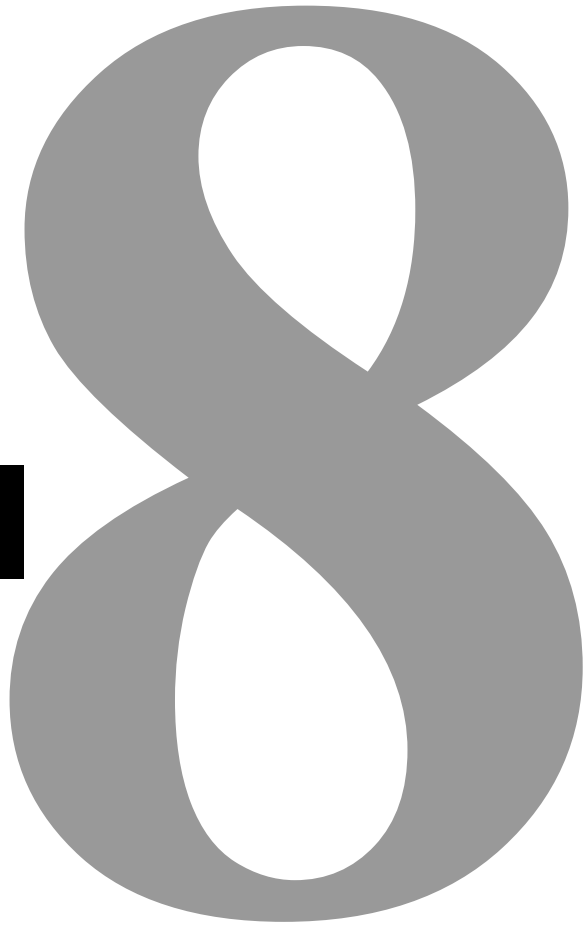
†ACTUAR Study Group (Corporate Authors)

Aguilar D, MD (Hospital Vivian Pellas Centro de Ortopedia, Managua, Nicaragua); Aguirre A, MD (Hospital civil de San Francisco Nayarit); Amadei R, MD (Hospital San Martin La Plata, Hospital de Alta Complejidad Cuenca Alta Cañuelas); Arroyo Sánchez CA, MD (Clínica Foscal Internacional); Baldy dos Reis F, MD (Federal University of Sao Paulo – UNIFESP); Balmaseda Manent R, MD (Hospital Docente Ortopedico Fructuoso Rodriguez); Barbosa Lourenco PR, MD (Hospital Quinta D'or); Barquet A, MD (Universidad CLAEH); Bayona V. J, MD (Clinica CES); Becerra G, MD (Hospital Occidente Kennedy, Universidad del Rosario Bogota, Colombia); Belangero W, MD, PhD (State University of Campinas – UNICAMP, Faculty of Medical Science Orthopedic and Traumatology Department); Bidolegui F, MD (Hospital Sirio Libanes); Bolaños R, MD (Hospital El Pilar); Calderón Gamba J, MD (Hospital Universitario de Santander); Cárdenas Quintero R, MD (Sociedad Venezolana de Cirugía Ortopédica y Traumatología – SVCOT); Dello Russo B, MD (Hospital Nacional de Pediatría Prof. J. P. Garrahan); Elias N, MD (Vila Velha Hospital); Esteves Pires R, MD, PhD (Universidade Federal de Minas Gerais); Estrella C. JM, MD (Instituto de Especialidades Médicas del Nordeste); Flores-Biard A, MD (Hospital Real San Jose Valle Real); Garuz M, MD (Hospital Santo Tomas); Gomez R, MD (Hospital Jose Rosales); Hernández Vivas G, MD (Instituto Hondureño de Seguridad Social); Jiménez Avila JM, MD, PhD (Tecnológico de Monterrey, Campus Guadalajara, Centro Medico Puerta de Hierro Norte); López Almejo L, MD (Universidad Autonoma de Coahuila); Lopez-Cervantes RE, MD (Hospital de Especialidades San Francisco De Asis); López-Mejia G, MD (Hospital Christus Muguerza Saltillo); Madrigal Gutiérrez R, MD (Servicios Médicos Municipales Cruz Verde Guadalajara, México); Martínez De Leon U, MD (UMAE 189 IMSS, Vera Cruz, México); Medina C, MD (IPS Universitaria Clínica León XIII); Mercado Salcedo EE, MD (Institute Mexicano del Seguro Social); Mingüer Vargas S, MD (Hospital Regional Presidente Juarez Issste Oaxaca); Minueza T, MD (Hospital Fundación Ruth Paz); Osma Rueda JL, MD (Sociedad Colombiana de cirugía ortopédica y traumatología – SCCOT, Universidad Industrial de Santander – UIS); Padilla LG, MD (Hospital Puerta de Hierro); Penteado da Silva LH, MD (Instituto de Ortopedia e Traumatologia – IOT, Hospital São Vicente de Paulo – HSVP); Pereira S, MD (Hospital Sirio Libanés); Quintero JE, MD (Fracturas y Fracturas, Hospital Universitario San Jorge); Quintero Hernandez S, MD (Hospital de la Santísima Trinidad); Quintero Laverde J, MD (Hospital Universitario Clínica San Rafael, Bogotá, Colombia); Rienzi Grassi V, MD (Hospital del Trauma, Asunción, Paraguay); Rodríguez López J, MD (Centro de Investigación y Docencia en Ciencias de la Salud Universidad Autónoma de Sinaloa); Salce I, MD (Clínica Delgado AUNA, Lima, Peru); Sepulveda Oyervides VM, MD (Hospital Regional del Issste, Monterrey, Nuevo Leon, México); Tabares Neyra H, MD, PhD (Centro de Investigaciones en Longevidad, Envejecimiento y Salud, CITED); Toledo-Infanson V, MD (Hospital General Agua Prieta, Servicios de Salud Sonora – SSA); Tort-Saade PJ, MD (Doctors' Center Hospital San Juan); Velarde J, MD (Hospital Santo Tomás); Vilensky E, MD (AEPSM/CASMU); Zuluaga M, MD (Clínica Imbanaco, Cali, Colombia)

PART III

Open Tibial Shaft Fractures: Current Management

CHAPTER 8



Open Tibial Shaft Fractures: Treatment Patterns in Latin America

Albright PD[1], MacKechnie MC[2], Roberts HJ[2], Shearer DW[2], Padilla L[3], Segovia J[4], Quintero JE[5], Amadei R[6], Baldy dos Reis F[7], Miclau T[2], ACTUAR Open Tibia Study Group[†]

[1]Western Michigan University School of Medicine
[2]Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[3]Hospital Puerta de Hierro, Guadalajara, México
[4]Hospital Central Instituto de Previsión Social, Asunción, Paraguay
[5]Fracturas y Fracturas, Pereira, Colombia
[6]Hospital Interzonal General de Agudos, San Martín de la Plata, La Plata, Buenos Aires, Argentina
[7]Federal University of São Paulo, São Paulo, Brazil

J Bone Joint Surg Am. 2020;102(22):e126-36

Abstract

Background: Open tibial shaft fractures are an important source of disability in Latin America. High-income countries (HICs) worldwide have established standardized treatment protocols for open tibial fractures, but less is known about their treatment in middle-income countries (MICs) in Latin America. This survey of Latin American orthopaedic surgeons characterizes open tibial fracture treatment patterns.

Materials and Methods: Orthopaedic surgeons from 20 national orthopaedic societies throughout Latin America completed an online survey assessing their treatment of open tibial fractures. Demographic information was collected. Treatment patterns were queried according to 2 groupings of Gustilo-Anderson (GA) fracture types: treatment of type-I and type-II fractures (GA-I/II) and treatment of type-III fractures (GA-III). Treatment patterns were evaluated across 4 domains: antibiotic prophylaxis, irrigation and debridement, fracture stabilization, and wound management. Summary statistics were reported; analysis was performed using the Fisher exact test ($p<0.05$).

Results: There were 616 survey participants from 20 Latin American countries (4 HICs and 16 MICs). Initial external fixation followed by staged internal fixation was preferred for GA-I/II (51.0%) and GA-III fractures (86.0%). Nearly one-third (31.5%) of GA-IIIB fractures did not receive a soft-tissue coverage procedure. Stratifying by country socioeconomic status, surgeons in MICs more commonly utilized delayed internal fixation for GA-I/II (53.3% versus 22.0%, $p<0.001$) and GA-III fractures (94.0% versus 80.4%, $p=0.002$). Surgeons in MICs more commonly used primary closure GA-I/II (88.9% versus 62.8%, $p<0.001$) and GA-III fractures (32.6% versus 9.8%, $p<0.001$).

Conclusion: This survey reports Latin American orthopaedic surgeons' treatment patterns for open tibial shaft fractures. Surgeons in MICs reported higher delayed internal fixation use for all fracture types, while surgeons in HICs more routinely avoid primary closure. Soft-tissue coverage procedures are not performed in nearly one-third of GA-IIIB fractures because of a lack of operative personnel and training.

Level of Evidence: None

Introduction

Musculoskeletal injuries contribute substantially to the global disease burden, and open tibial fractures are a leading cause of morbidity.[1] Moreover, more than 90% of injury-related deaths occur in low-and middle-income countries (LMICs).[1,2] Latin America has a rising open tibial fracture burden due to road traffic accidents, with as many as 50,000 open fractures per year in some countries and complication rates as high as 20%.[3,4] Yet, little remains known regarding the true burden or treatment of these injuries in Latin America.[5-7]

Open tibial fractures are traumatic injuries that require emergency orthopaedic treatment. The standard of care for open tibial shaft fractures includes early prophylactic antibiotics, surgical wound debridement, and fracture stabilization, all of which play a critical role in reducing long-term morbidity.[6-11] However, nationally recognized best practices and treatment patterns for open tibial shaft fractures across Latin America are less documented. A recent study found that 26% to 50% of middle-income countries (MICs) worldwide had formalized guidelines for open fracture treatment,[12] but few Latin American countries had available guidelines.[13-16] While factors such as access to resources and the type of health-care system can determine treatment patterns, it is challenging to address orthopaedic care gaps without understanding current treatment patterns and how such preferences differ among the countries surveyed. Therefore, this study aims to provide insight into the treatment of open tibial shaft fractures in Latin America.

Materials and Methods

Survey Design and Distribution

We performed a cross-sectional survey of orthopaedic surgeons practicing in Latin America. We utilized a convenience sampling method of members of an academic orthopaedic research consortium[17] and members of Latin American orthopaedic societies. Institutional review board approval was obtained from the primary study institution.

The survey assessed surgeons' treatment preferences for open tibial fractures. Survey questions were developed based on the existing literature, with input from 3 United States fellowship-trained orthopaedic trauma surgeons and 3 Latin American orthopaedic surgeons. The English survey was translated into Spanish by 2 bilingual Latin American orthopaedic trauma surgeons. Subsequently, the Spanish survey was reviewed after translation back into English and distributed to the authorship group for final review. The survey included demographic information about the treating surgeon and his or her practice, including sex, country, practice environment, and number of open tibial fractures that are treated per year. Open tibial fracture treatment was queried according to 2 groupings determined by the Gustilo-Anderson (GA) classification:[18] the first group included treatment of type-I and type -II fractures (GA-I/II), and the second group included treatment of type-III fractures (GA-III). The survey queried responses relating to 4 open fracture treatment domains: antibiotic prophylaxis, irrigation and debridement, fracture stabilization, and wound management (see Appendix).

To reach respondents, at least 1 board member of each Latin American orthopaedic society was contacted to request assistance with survey distribution to the members of his or her respective organization. In order to increase survey response, it was requested that board and society members distribute the survey to local orthopaedic surgeons who treat open fractures. In order to avoid duplicate responses and to make them identifiable, respondents provided their name and

hospital. Additionally, each orthopaedic society reported if society or national guidelines exist for open fracture treatment. Follow-up emails were sent at 2-month intervals, and the survey was closed after 10 months. Responses were collected utilizing Research Electronic Data Capture (REDCap).[19]

Statistical Methods

Summary statistics were calculated, and responses were categorized according to the World Bank data regarding country income status as either high-income countries (HICs) or MICs, where MICs include both upper-middle-income and lower-middle-income countries.[20] At the time of writing, no Latin American country represented in this survey was classified as a low-income country. Comparisons between groups were performed using two-tailed Fisher's exact tests with $\alpha = 0.05$ significance level. All analyses were performed using STATA SE version 15 (StataCorp).

Results

There were 616 survey participants from 20 countries (4 HICs and 16 MICs; Figure 1), with the majority from MICs (91.5%). The majority of respondents were men (91.7%), practiced in an urban setting (96.1%), and had not completed musculoskeletal trauma fellowships (62.4%) (Table 1). Just over one-quarter (26.5%) stated that their institution has a formalized open tibial fracture treatment protocol. Of the 20 orthopaedic societies, 6 (30%) stated that either societal or national open tibial fracture treatment guidelines exist, while 14 (70%) either stated that no guidelines exist or did not respond (Table 2). More than half of respondents treated > 10 open tibial fractures per year. One-third reported that the majority of patients with open tibial fractures at their hospital present at > 24 hours after injury.

Regarding antibiotic prophylaxis, 92.6% reported administering intravenous antibiotics alone for patients with GA-I/II fractures, while 21.7% administered local antibiotics with intravenous antibiotics for GA-III fractures (Table 3). The majority of respondents felt that the optimal time for antibiotic delivery is within 3 hours of hospital arrival for both GA-I/II (89.0%) and GA-III (93.4%) fractures. However, respondents frequently encountered delays in antibiotic administration, with about one-third stating antibiotics are typically delivered at > 3 hours after patient arrival for both GA-I/II (34.6%) and GA-III (31.5%) fractures. For GA-I/II fractures, most respondents administer first-generation cephalosporins alone (64.5%), with some respondents adding third-generation cephalosporins (14.8%) or aminoglycosides (14.7%). The antibiotic administered to patients with GA-III fractures was variable, with first-generation cephalosporins (30.7%) and aminoglycosides (30.7%) most commonly reported.

Regarding irrigation and debridement, the majority of respondents felt that optimal definitive operative debridement should occur within 6 hours of presentation for GA-I/II (79.1%) and GA-III (90.5%) fractures (Table 3). However, the reported time to operative debridement in practice differed considerably from the optimal time, with approximately half of GA-I/II (53.9%) and GA-III (46.7%) fractures reportedly treated between 6 and 24 hours after presentation to the hospital. Respondents most commonly cited a lack of available operative personnel or space and delayed patient arrival as the reasons for delayed definitive debridement.

Initial external fixation followed by staged internal fixation was most commonly reported for both GA-I/II (51%) and GA-III (86%) fractures (Table 4). Definitive external fixation was infrequently reported, and more often for GA-III fractures (7.4%) than GA-I/II fractures (1.0%). When performing internal fixation, intramedullary nailing was the preferred strategy for GA-I/II fractures (87.5%) and for GA-III fractures (84.4%). The most commonly cited reason for delayed internal fixation for all fracture types was infection risk.

Regarding wound management, most reported primary closure for GA-I/II fractures (87.5%), and delayed closure for GA-III fractures (69.8%) (Table 5). However, nearly one-third did not use soft-tissue coverage procedures to treat GA-IIIB open tibia fractures. The most commonly cited reasons for not using soft-tissue coverage procedures to treat GA-IIIB fractures. The most commonly cited reasons for not using these procedures included lack of plastic surgeons, surgeon preference, and surgeon training level. When primary closure was not possible, the majority reported using negative-pressure wound therapy (57.8%) or saline-solution-soaked dressings (39.4%).

When comparing respondents from MICs with those from HICs, surgeons from MICs more frequently reported time to antibiotic administration as > 3 hours after patient presentation than surgeons from HICs for GA-I/II (36.6% versus 19.6%, p =0.014) and GA-III (33.3% versus 19.6%, p =0.059) fractures (Table IV). Furthermore, surgeons from MICs reported utilizing delayed internal fixation more commonly for GA-I/II (53.3% versus 22.0%, p <0.001) and GA-III (94.0% versus 80.4%, p = 0.002) fractures. Surgeons from MICs also more commonly reported attempting primary closure for both GA-I/II (88.9% vs. 62.8%, p <0.001) and GA-III (32.6% vs. 9.8%, p <0.001) fractures. Finally, when comparing by surgeons' years in practice, there was decreased primary closure use for GA-III with increasing practice years (0 to 5 years, 38.2%; 6 to 10 years, 35.0%; 11 to 15 years, 32.2%; 16 to 20 years, 27.6%; and >20 years, 21.4%; p = 0.020).

Discussion

To our knowledge, this cross-sectional study is the first to examine the preferred open tibial fracture treatment methodology in a cohort of Latin American orthopaedic surgeons. We have identified differences in treatment patterns among Latin American HICs and MICs, particularly pertaining to antibiotic prophylaxis, fracture stabilization, and wound coverage. Furthermore, we have identified potentially modifiable factors that may be addressed to improve open fracture treatment.

This study's strength is in the novelty of the data that are included and the diversity of the countries that are represented, particularly given its focus on a world region where collaborative and multicenter studies are limited.[17,21] The results are consistent with previous studies. In an international survey that included orthopaedic surgeons from each continent, Bhandari et al. queried tibial shaft fracture treatment; among 444 respondents, they found that internal fixation is commonly used across open fracture types (type I, 95.5%, type II: 88.1%, and type IIIA: 67.6%).[22] They did not, however, distinguish between index internal fixation and external fixation followed by delayed internal fixation, or evaluate the reasons for the potential treatment differences. Furthermore, the majority of the respondents were from North America (51.7%), with only 65 responses (14.6%) from South America. A Canadian survey with 268 respondents

found that 83% of respondents preferred to use intramedullary nailing for all open tibial fractures, but they did not distinguish implant choice by open fracture type or the choice between primary and delayed internal fixation.[23] Studies specific to Latin America are composed of small analyses from single institutions. A study from Guanajuato, Mexico, prospectively recorded the frequency and fracture type encountered over 1 year at their institution, in which they reported 66 open tibial fractures.[24] A similar study from Mexico City reviewed case logs over 4 years and identified 82 tibial fractures but did not specify whether they were open or closed.[26] Furthermore, neither study noted treatment protocols or fracture stabilization strategies. Thus, our study provides novel insights into the current standards of care in Latin America. These results highlight a need for the development of treatment guidelines at an orthopaedic society or national level. These guidelines should be specific for patients who present acutely and for those who present in a delayed manner. The guidelines developed by organizations such as the American Academy of Orthopaedic Surgeons or the Orthopaedic Trauma Association may not be generalizable to Latin American countries because of the high delayed patient presentation rate. Globally, there are few countries that have developed formal treatment guidelines for these injuries.[12]

These data may provide an opportunity for standardization and modernization of treatment protocols in Latin America. Based on data primarily from resource-rich settings, primary intramedullary nailing is the preferred management for low-energy and some high-energy open tibial shaft fractures.[26-28] Some meta-analyses have corroborated this treatment preference.[30,31] However, our study demonstrated a high delayed internal fixation rate, particularly among MICs. This could be due to a number of factors, including surgeon education, resource limitations, patient factors, or concern that the local environment differs from resource-rich environments.

For example, one-third of respondents in this study indicated that the majority of patients at their institution presented to the hospital at > 24 hours after injury, which increases infection risk. Respondents reported that their primary reason for using delayed internal fixation was infection risk. These findings are consistent with the previous open tibial fracture literature from Latin America. One Brazilian study found that 44% of patients with open tibial fractures were treated > 24 hours after injury, which they attributed to late presentation, lack of hospital beds, extended transport time, and operating room unavailability.[32] A study in Mexico found that 80% of their cohort was treated with delayed internal fixation, commonly because of fracture severity or lack of implant availability at the initial debridement.[33] Additional studies are needed to explore the rationale for performing delayed internal fixation for open tibial fracture and to find solutions to reduce delayed presentation. This has been a notable lack of pre-hospital care and resource availability in non-trauma-designated hospitals in Latin LMICs, and recent evidence suggests that the adoption of well-coordinated trauma systems is critical for improving musculoskeletal trauma care, including open fractures.[13] Indeed, the most recent edition of *Essential Surgery: Disease Control Priorities* from the World Bank Group has incorporated open fracture care into its essential trauma care guidelines for primary level hospitals[34]. Furthermore, training rural surgeons in basic open fracture care, as is being done by Mexican and Argentinian national orthopaedic societies, and developing guidelines for acute and delayed open fracture presentation may also address the issue of delayed care.

Finally, our study found higher delayed closure rates among Latin American respondents from HICs and similar primary closure rates among Latin American respondents from MICs as compared with recent North American studies. A study of 119 open fractures at a single institution in the United States found that primary closure was frequently used for type-I (88%), type-II (86%), and type-IIIA (75%) fractures.[34] In 2 separate Canadian studies, the overall primary closure rate for type-I to type-IIIA open tibial fractures was 70% and 77%, respectively, and the majority of type-I (92% and 93%, respectively) and type-II (79% and 95%, respectively) fractures in each study were closed primarily.[35,36] Finally, in a 2007 survey of current open fracture teaching among United States orthopaedic residencies, respondents frequently utilized primary closure for type-I (88%) and type-II (86%) fractures.[37] However, the higher delayed closure rate among Latin American respondents from HICs may be due to increased delays in patient presentation to the hospital as compared with the United States and Canada. Thus, direct comparisons of our data to HIC data from other countries may be difficult. Further work is necessary to explore this issue. Additionally, the higher primary closure rate among surgeons in Latin American MICs compared with HICs may be because of concern about their ability to return to the operating room due to the lack of personnel, operating room capacity, or patient ability to pay. Thus, rather than performing multiple take-back operations, they may opt to primarily close wounds at the initial debridement and fracture stabilization.

Our study demonstrated that soft-tissue flap procedures are not performed in nearly one-third of GA-IIIB tibial fractures, a finding that was evident among surgeons in MICs. This likely represents limited access to plastic surgeons, as 40% of respondents attributed lack of flap coverage to lack of access to plastic surgeons and 23% cited their own training level or comfort with flap procedures. These findings support the investment into increasing plastic surgery capacity or training orthopedic surgeons to perform flap procedures to address this treatment gap.[38]

While this study provides novel insight into open tibial fracture treatment by Latin American orthopaedic surgeons, it has several limitations. We were unable to obtain a response rate for this survey given how it was distributed to orthopaedic societies, the ACTUAR Open Tibia Study Group network[17], and Latin American orthopaedic surgeons. We sought to maximize responses by encouraging respondents to distribute the survey to their colleagues and encouraging orthopaedic societies to distribute the survey to their membership roster. Members of the boards of directors or their delegates were responsible for survey distribution. Some individuals distributed the survey to their membership roster, while others distributed the survey within their organization to a targeted audience of orthopaedic trauma surgeons known to treat open tibial fractures. We attempted to determine survey penetrance and provide contextual evidence for the number of orthopaedic surgeons in each country by retrieving data regarding the number of practicing orthopaedic surgeons in each society and an estimate of the number of surgeons who received the survey. However, we were ultimately unable to determine if a survey was received by society members. Furthermore, given the chain-referral sampling methodology and the possibility that individuals providing surveys may have been contacted outside of a national society, we were unable to accurately calculate response rate. Nonetheless, the number of respondents to this survey is small relative to the number of practicing orthopaedic surgeons in Latin America. Therefore, the results may not be generalizable. We also recognize that the majority of respondents were urban surgeons. It is possible that urban surgeons were more likely

to receive or complete the survey, or a disproportionate concentration of orthopaedic surgeons in urban Latin America may be reflected. While the treatment protocols assessed in this survey are based on the available literature and the input of subject matter experts, the survey that we used is not validated, and psychometric properties such as the Cronbach alpha and eigenvalues are unknown as they were not assessed during survey piloting.

To our knowledge, this study is first to date describing open tibial fracture treatment patterns by orthopaedic surgeons across Latin America. We determined that there are significant differences pertaining to fracture stabilization and wound management among Latin American HICs and MICs. Future research is needed to clarify the reasons for these discrepancies and to establish setting-specific guidelines.

References

1. Mock C, Cherian MN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Clin Orthop*. 2008;466(10):2306-2316. doi:10.1007/s11999-008-0416-z
2. Moroz PJ, Spiegel DA. The World Health Organization's Action Plan on the Road Traffic Injury Pandemic: Is There Any Action for Orthopaedic Trauma Surgeons? *J Orthop Trauma*. 2014;28(6):4.
3. Fraser B. Traffic accidents scar Latin America's roads. *Lancet Lond Engl*. 2005;366(9487):703-704. doi:10.1016/S0140-6736(05)67158-9
4. Orihuela-Fuchs VA, Fuentes-Figueroa S. [Infection rate in open fractures adjusted for the degree of exposure]. *Acta Ortop Mex*. 2013;27(5):293-298.
5. INORMUS Investigators. INternational ORthopaedic MUlticentre Study (INORMUS) in Fracture Care: Protocol for a Large Prospective Observational Study. *J Orthop Trauma*. 2015;29 Suppl 10:S2-6. doi:10.1097/BOT.0000000000000404
6 Kohlprath R, Assal M, Uckay I, et al. [Open fractures of the tibia in the adult: surgical treatment and complications]. *Rev Med Suisse*. 2011;7(322):2482,2484-2488
7. Mundi R, Chaudry H, Niroopan G, Petrisor B, Bhandari M. Open Tibial Fractures: Updated Guidelines for Management. JBJS Reviews. 2015'3(2):e1
8. Cross WW, Swiontkowski MF. Treatment Principles in the Management of Open Fractures. *Indian J Orthop*. 2008;42(4):377-386
9. Duyos OA, Beaton-Comulada D, Davila-Parrilla A, Perez-Lopez JC, Ortiz K, Foy-Parrilla C, Lopez-Gonzalez F. Management of open tibial shaft fractues does the timing of surgery affect outcomes? *J Am Acad Orthop Surg*. 2017;25(3):230-238
10. Clelland SJ, Chauhan P, Mandari FN. The epidemiology and management of tibia and fibula fractures at Kilimanjaro Christian Medical Centre (KCMC) in Northern Tanzania. *Pan Afr Med J*. 2016;25. doi:10.11604/pamj.2016.25.51.10612
11. Giannoudis PV, Papakostidis C, Roberts C. A Review of the Management of Open Fractures of the Tibia and Femur. *J Bone Jt Surg*. 2006;88(3):281-289
12. Miclau T, Hoogervorst P, Shearer DW, et al. Current Status of Musculoskeletal Trauma Care Systems Worldwide. *J Orthop Trauma*. 2018;32 Suppl 7:S64-S70. doi:10.1097/BOT.0000000000001301
13. Nogueira, José, Braga, Gilberto, Cunha, Fernando. Tratamento Primário das Fraturas Expostas. Saude Direta. http://saudedireta.com.br/protocolos.php?busca=exposta&x=0&y=0. Published December 18, 2009
14. Instituto Guatemalteco de Seguridad Social. Guia de Práctica Clínica Basada en Evidencia (GPC-BE) no. 70. Manejo de Fracturas Expuestas. 2016. Accessed 2020 Jul 20. https://www.igssgt.org/wp-content/uploads/images/gpc-be/traumatologia-y-ortopedia/GPC-BE-No70-Manejo-de-las-Fracturas-Expuestas.pdf
15. Hernandez, David, Zambrano, Edson. Manejo de fracturas expuestas. Instituto Guatemalteco de Seguridad Social. https://www.igssgt.org/wp-content/uploads/images/gpc-be/traumatologia-y-ortopedia/GPC-BE-No-70-Manejo-de-las-Fracturas-Expuestas.pdf.
16. Rodriguez, Maria, Menjivar, Violeta, Fiallos, Eduardo. Guías Clínicas de Ortopedia. Ministerio de Salud-El Salvador. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjNp7iaqsroAhXMW80KHQsiBT0QFjAAegQIBBAB&url=http%3A%2F%2Fasp.salud.gob.sv%2Fregulacion%2Fpdf%2Fguia%2FGuias_Clinicas_de_Ortopedia.pdf&usg=AOvVaw1GSYcPFBcz_6FgGhrnyTg-. Published February 2012.

17. Miclau T, MacKechnie MC, Shearer DW. Asociacion de Cirujanos Traumatologos de las Americas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl 7:S8-S11. doi:10.1097/BOT.0000000000001302
18. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma*. 1984;24(8):742-746. doi:10.1097/00005373-198408000-00009
19. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010
20. The World Bank. Data: Country and Lending Groups 2020. Access 2020 Apr 10. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
21. Moraes VY de, Belloti JC, Faloppa F, Bhandari M. Collaborative multicenter trials in Latin America: challenges and opportunities in orthopedic and trauma surgery. *Sao Paulo Med J Rev Paul Med*. 2013;131(3):187-192. doi:10.1590/1516-3180.2013.1313555
22. Bhandari M, Guyatt GH, Swiontkowski MF, et al. Surgeons' preferences for the operative treatment of fractures of the tibial shaft. An international survey. *J Bone Joint Surg Am*. 2001;83(11):1746-1752. doi:10.2106/00004623-200111000-00020
23. Busse JW, Morton E, Lacchetti C, Guyatt GH, Bhandari M. Current management of tibial shaft fractures: a survey of 450 Canadian orthopedic trauma surgeons. *Acta Orthop*. 2008;79(5):689-694. doi:10.1080/17453670810016722
24. Domínguez Gasca LG, Orozco Villaseñor SL, Domínguez Gasca LG, Orozco Villaseñor SL. Frecuencia y tipos de fracturas clasificadas por la Asociación para el Estudio de la Osteosíntesis en el Hospital General de León durante un año. *Acta Médica Grupo Ángeles*. 2017;15(4):275-286.
25. Díez GMP, Macías HSI, Ramírez PE, Chávez ADD, Soria BMA, Granados RR, Balesteros RF. Características epidemiológicas de pacientes adultos atendidos por fractures en el Instituto Nacional de Rehabilitación. Investig En Discapac. 2013;2(2):51-4.
26. Court-Brown CM, McQueen MM, Quaba AA, Christie J. Locked intramedullary nailing of open tibial fractures. *J Bone Joint Surg Br*. 1991;73(6):959-964.
27. Bone LB, Kassman S, Stegemann P, France J. Prospective study of union rate of open tibial fractures treated with locked, unreamed intramedullary nails. *J Orthop Trauma*. 1994;8(1):45-49. doi:10.1097/00005131-199402000-00010
28. Henley MB, Chapman JR, Agel J, Harvey EJ, Whorton AM, Swiontkowski MF. Treatment of type II, IIIA, and IIIB open fractures of the tibial shaft: a prospective comparison of unreamed interlocking intramedullary nails and half-pin external fixators. *J Orthop Trauma*. 1998;12(1):1-7. doi:10.1097/00005131-199801000-00001
29. Bhandari M, Guyatt GH, Swiontkowski MF, Schemitsch EH. Treatment of open fractures of the shaft of the tibia. *J Bone Joint Surg Br*. 2001;83(1):62-68. doi:10.1302/0301-620x.83b1.10986
30. Foote CJ, Guyatt GH, Vignesh KN, et al. Which Surgical Treatment for Open Tibial Shaft Fractures Results in the Fewest Reoperations? A Network Meta-analysis. *Clin Orthop*. 2015;473(7):2179-92. Epub 2015 Feb 28.
31. Almeida Matos M, Castro-Filho RN, Pinto da Silva BV. Risk factors associated with infection in tibial open fractures. *Rev Fac Cienc Méd Univ Nac Córdoba*. 2013;70(1):14-8.

32. Ruiz-Martínez F, Caldelas-Cuéllar E, Sánchez Sánchez M. Epidemiología y resultados clínicos de las fracturas expuestas de la tibia. *Acta Ortop Mex*. 2001;15(6):288-95.
33. McCord C, Kruk M, Mock C, Cherian M, von Schreeb J, Russell S, English M. Organization of essential services and the role of first-level hospitals. In: Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN, editors. *Disease control priorities: essential surgery*. 3rd ed, vol 1. World Bank Group; 2015. p213-31.
34. DeLong WG, Born CT, Wei SY, Petrik ME, Ponzio R, Schwab CW. Aggressive treatment of 119 open fracture wounds. *J Trauma*. 1999;46(6):1049-54.
35. Moola FO, Carli A, Berry GK, Reindl R, Jacks D, Harvey EJ. Attempting primary closure for all open fractures: the effectiveness of an institutional protocol. *Can J Surg J Can Chir*. 2014;57(3):E82-8.
36. Jenkinson RJ, Kiss A, Johnson S, Stephen DJG, Kreder HJ. Delayed wound closure increases deep-infection rate associated with lower-grade open fractures: a propensity-matched cohort study. *J Bone Joint Surg Am*. 2014;96(5):380-6.
37. Lavelle WF, Uhl R, Krieves M, Drvaric DM. Management of open fractures in adult patients: current teaching in ACGME accredited residency programs. *J Surg Orthop Adv*. 2007;16(3):111-7.
38. Albright PD, MacKechnie MC, Jackson JH, Chopra A, Holler JT, Flores Biard A, Padilla LG, Morshed S, Miclau T, Shearer DW, Terry MJ. Knowledge deficits and barriers to performing soft-tissue coverage procedures: an analysis of participants in an orthopaedic surgical skills training course in Mexico. *OTA Int*. 2019;2(4):e044.
39. Feoli E, Badilla V, Bermudez M, Mendez E, Badilla X. Surgery in Costa Rica. *Arch Surg*. 2002;137(12):1435-40.
40. Sociedad Puertorriquena de Ortopedia y Traumatología. Directorio. Accessed 2020 Apr 10. http://spot.ortopediapr.org/directorio.

Figure 1. Map of survey respondents demonstrating high-income and middle-income Latin American countries. (MICs include lower-middle-income and upper-middle-income countries; 13 respondents did not identify their country).

Table 1. Demographic data

Characteristic	Total (N = 616)*
Sex (Male)	565 (91.7)
World Bank Profile	
High-income country	51 (8.5)
Middle-income country †	552 (91.5)
Practice environment	
Academic	35 (5.7)
Private practice	106 (17.4)
Public	89 (14.6)
Multiple	380 (62.3)
Practice location	
Urban (city)	588 (96.1)
Suburban	19 (3.1)
Rural	5 (0.8)
Years in practice	
0 to 5	112 (19.6)
6 to 10	121 (21.2)
11 to 15	87 (14.1)
16 to 20	77 (13.5)
>20	174 (30.5)
Fellowship in musculoskeletal trauma	
Yes	230 (37.6)
No	382 (62.4)
Number of open tibia fractures treated each year	
0 to 10	217 (36.2)
11 to 20	176 (29.4)
21 to 30	93 (15.5)
31 to 40	30 (5.0)
41 to 50	32 (5.3)
>50	51 (8.5)
Percentage of fractures presenting within 24 hours of injury	
<10%	71 (11.6)
10% to 25%	61 (10.0)
25% to 50%	71 (11.6)
50% to 75%	95 (15.5)
75% to 90%	133 (21.7)
>90%	181 (29.6)

Institution has a formal open fracture treatment protocol	
Yes	163 (26.5)
No	451 (73.5)

*Various data were not reported by all respondents. All data are frequency of response: number (%). †Includes countries defined as upper-middle and lower-middle income countries.

Table 2. Latin American national orthopaedic societies*

National Society	Country	Reported Membership Count	Estimated Survey Distribution	Surveys Completed
Asociación Argentina del Trauma Ortopédico (AATO)	Argentina	500	500	46
Sociedad Boliviana de Ortopedia y Traumatología (SBOLOT)	Bolivia	NR	NR	3
Sociedade Brasileira de Trauma Ortopédico (SBTO)/ Sociedade Brasileira Ortopedia Traumatología (SBOT)	Brazil	470/15,000	470/1,500	45
Sociedad Chilena de Ortopedia y Traumatología (SCHOT)	Chile	74	74	7
Sociedad Colombiana de Cirugía Ortopédica y Traumatología (SCCOT)	Colombia	1,411	1,411	62
Asociación Costarricense de Ortopedia y Traumatología (ACOT)	Costa Rica	85[39]	NR	7
Sociedad Cubana de Ortopedia y Traumatología (SCOT)	Cuba	2,284	1,142	10
Sociedad Dominicana de Ortopédia y Traumatología (SDOT)	Dominican Republic	703	21	14
Sociedad Ecuatoriana de Ortopédia y Traumatología (SEOT)	Ecuador	500	500	23
Asociación Salvadoreña de Ortopédia y Traumatología (ASOT)	El Salvador	55	55	12
Asociación Guatemalteca de Ortopédia y Traumatología (AGOT)	Guatemala	1,200	1,200	4
Asociación de Cirugía Ortopédica y Traumatología de Honduras (ACOTH)	Honduras	135	135	1
Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT)	Mexico	3,100	3,100	205
Asociación Nicaraguense de Ortopedia y Traumatología (ANOT)	Nicaragua	230	230	39
Sociedad Panameña de Ortopedia y Traumatología (SPOT)	Panama	180	180	10
Sociedad Paraguaya de Ortopedia y Traumatología (SPOT)	Paraguay	250	60	53
Sociedad Peruana de Ortopedia y Traumatología (SPOT)	Peru	500	400	9
Sociedad Puertorriqueña de Ortopedia y Traumatología (SPOT)	Puerto Rico	144[40]	NR	1
Sociedad de Ortopedia y Traumatología del Uruguay (SOTU)	Uruguay	358	358	33
Sociedad Venezolana de Cirugía Ortopédica y Traumatología (SVCOT)	Venezuela	2,003	1,200	19

*NR = not reported. Various data were not reported by all respondents.

Table 3. Treatment decisions by domains of open fracture management: antibiotic prophylaxis and irrigation and debridement

	Gustilo-Anderson Type I or II	Gustilo-Anderson Type III
Antibiotic prophylaxis		
Route of antibiotic administration		
Intravenous only	560 (92.6)	468 (76.6)
Local antibiotics only	1 (0.2)	8 (1.3)
Intravenous with local antibiotics	44 (7.3)	132 (21.7)
Optimum time to antibiotic delivery		
<3 hours	544 (89.0)	570 (93.4)
3 to 6 hours	60 (9.8)	30 (4.9)
6 to 24 hours	6 (1.0)	8 (1.3)
>24 hours	1 (0.2)	2 (0.3)
Actual average time to antibiotic delivery		
<3 hours	399 (65.4)	417 (68.5)
3 to 6 hours	152 (24.9)	139 (22.8)
6 to 24 hours	57 (9.3)	50 (8.2)
>24 hours	2 (0.3)	3 (0.5)
Antibiotic regimen †		
First-generation cephalosporin	466 (64.5)	324 (31.8)
Third-generation cephalosporin	107 (14.8)	204 (20.0)
Aminoglycoside	106 (14.7)	324 (31.8)
Penicillin	23 (3.2)	51 (5.0)
Vancomycin	5 (0.7)	22 (2.2)
Piperacillin/tazobactam	1 (0.1)	3 (0.3)
Metronidazole	14 (1.9)	92 (9.0)
Irrigation and debridement		
Optimum time to definitive operative debridement		
<6 hours	484 (79.1)	554 (90.5)
6 to 24 hours	103 (16.8)	43 (7.0)
24 to 48 hours	3 (0.5)	8 (1.3)
Time to debridement is unimportant	22 (3.6)	7 (1.1)
Actual average time to definitive operative debridement		
<6 hours	239 (39.1)	290 (47.4)
6 to 24 hours	330 (53.9)	286 (46.7)
24 to 48 hours	31 (5.1)	23 (3.8)
>48 hours	12 (2.0)	13 (2.1)
Reason for delayed debridement		
Surgeon choice/preference	15 (2.5)	13 (2.2)
Lack of available operative personnel or space	296 (50.3)	301 (51.1)
Patient cannot afford expenses	39 (6.6)	35 (5.9)
Lack of necessary equipment/implants	36 (6.1)	46 (7.8)
Delayed patient arrival	203 (34.5)	194 (32.9)

All data are frequency of response: number (%). Various data were not reported by all respondents.
†Multiple responses could be selected for the antibiotic regimen.

Table 4. Treatment decisions by domains of open fracture management: fracture stabilization and wound management

	Gustilo-Anderson Type I or II	Gustilo-Anderson Type III	All Fracture Types
Fracture stabilization			
Treatment method			
Primary internal fixation	291 (47.7)	40 (6.6)	
Delayed internal fixation	311 (51.0)	524 (86.0)	
Definitive external fixation	6 (1.0)	45 (7.4)	
Definitive cast or splint	2 (0.3)	0	
Primary method of internal fixation			
Locking plate	38 (6.3)	68 (12.1)	
Non-locking plate	37 (6.2)	20 (3.6)	
Unreamed intramedullary nail	262 (43.7)	228 (40.6)	
Reamed intramedullary nail	263 (43.8)	246 (43.8)	
Primary reason for using delayed internal fixation			
Infection risk	183 (59.2)	417 (79.9)	
Cost of implants	61 (19.7)	47 (9.0)	
Training/level of comfort	14 (4.5)	19 (3.6)	
Other	51 (16.5)	39 (7.5)	
Wound management			
Time of wound closure			
Primary closure at time of definitive fixation	534 (87.5)	184 (30.2)	
Delayed closure	76 (12.5)	425 (69.8)	
Surgical specialty responsible for the majority of flap procedures			
Orthopaedics			108 (18.4)
Plastic surgery			428 (72.9)
General surgery			3 (0.5)
Orthopaedics and plastic surgery			48 (8.2)
The majority of Gustilo-Anderson type-IIIB fractures are treated with flap procedures			
Yes			417 (68.5)
No			192 (31.5)
Reason for not using flap procedures in your hospital			
Surgeon training level/comfort		54 (23.7)	
Surgeon preference		30 (13.2)	
Lack of available operative personnel or space		22 (9.6)	
Patient cannot afford expenses		10 (4.4)	
Lack of necessary equipment/implants		17 (7.5)	

Lack of plastic surgeons	95 (41.7)
Treatment used when wound cannot be closed primarily	
Negative-pressure wound therapy	331 (57.8)
Saline-solution-soaked dressings	226 (39.4)
Antibiotic bead pouch	16 (2.8)

*All data are frequency of response: number (%). Various data were not reported by all respondents.

Table 5. Comparison of treatment preference by HIC versus MIC*

	Gustilo-Anderson Type I or II		P Value	Gustilo-Anderson Type III		P Value
	HIC (n = 51)	MIC (n = 552)		HIC (n = 51)	MIC (n = 552)	
Average time to antibiotic delivery						0.059
<3 hours	41 (80.4)	350 (63.4)	0.014	41 (80.4)	368 (66.7)	
>3 hours	10 (19.6)	202 (36.6)		10 (19.6)	184 (33.3)	
Average time to operative debridement						0.062
<24 hours	50 (98.0)	508 (92.5)	0.244	51 (100.0)	513 (93.4)	
>24 hours	1 (2.0)	41 (7.5)		0 (0.0)	36 (6.6)	
Utilize primary versus delayed internal fixation						0.002
Primary	39 (78.0)	247 (45.7)	<0.001	10 (19.6)	30 (6.0)	
Delayed	11 (22.0)	294 (54.3)		41 (80.4)	474 (94.0)	
Utilize primary versus delayed closure						<0.001
Primary	32 (62.8)	491 (89.8)	<0.001	5 (9.8)	178 (32.6)	
Delayed	19 (37.2)	56 (10.2)		46 (90.2)	368 (67.4)	
Use soft tissue coverage procedures for 3B fractures						0.270
Yes	-	-	-	39 (76.5)	374 (68.5)	
No	-	-		12 (23.5)	172 (31.5)	

*All data are frequency of response: number (%). Various data were not reported by all respondents. All tests of significance were completed with the Fisher exact test (α=0.05). HIC= high-income country and MIC=middle-income country.

Acknowledgements

†ACTUAR Open Tibia Study Group

Asociación Argentina del Trauma Ortopédico (AATO)

Amadei R, MD (Hospital Interzonal General de Agudos); Bidolegui F, MD (Hospital Sirio Libanés de Buenos Aires); Dello Russo B, MD (J. P. Garrahan Hospital Nacional de Pediatria Ciudad Autónoma de Buenos Aires); Garabano G, MD (Hospital Británico de Buenos Aires); Pereira S, MD (Hospital Sirio Libanés de Buenos Aires); Pesciallo C, MD (Hospital Británico de Buenos Aires)

Sociedad Boliviana de Ortopedia y Traumatología (SBOLOT)

Gutierrez Escobar R, MD (Clínica Aranjuez)

Sociedade Brasileira de Trauma Ortopédico (SBTO)

Baldy dos Reis F, MD (Federal University of São Paulo); Belangero WD, MD, PhD (Universidade Estadual de Campinas); Caiero MT, MD (Instituto de Ortopedia e Traumatologia); Fischer ST, MD, MSc (Hospital do Trabalhador); Giordano V, MD, PhD, FBCS (Hospital Municipal Miguel Couto); Hungria JOS, MD (Hospital da Irmandade de Misericórdia da Santa Casa de São Paulo), Kojima K, MD, PhD (University of São Paulo); Penteado da Silva LH, MD (Instituto de Ortopedia e Traumatologia de Passo Fundo); Pires Esteves, R, MD, PhD (Universidade Federal de Minas Gerais)

Sociedade Brasileira de Ortopedia e Traumatologia (SBOT)

Baldy G (Universidade Cidade de São Paulo); Klay Machado J, MD (Porto Dias Hospital and Adventist Hospital of Belém); Matheus Guimarães J, MD (Instituto Nacional de Traumatologia e Ortopedia)

Sociedad Chilena de Ortopedia y Traumatología (SCHOT)

Fuentes Morales E, MD (Clínica Ciudad del Mar)

Sociedad Colombiana de Cirugía Ortopédica y Traumatología (SCCOT)

Osma JL, MD (Universidad Industrial de Santander); Quintero JE, MD (Fracturas y Fracturas); Triana MA, MD (Fundación Cardioinfantil); Vargas RA, MD (Universidad Nacional de Colombia); Zuluaga M, MD (Centro Medico Imbanaco)

Sociedad Cubana de Ortopedia y Traumatología (SCOT)

Balmaseda Manent R, MD (Hospital Fructuoso Rodriguez); Ceballos Mesa A, MD (Universidad Medica de La Habana); Tabares Neyra H, MD (Universidad Medica de La Habana)

Sociedad Dominicana de Ortopédia y Traumatología (SDOT)

Landrón J, MD (Hospital Ney Arias Lora)

Sociedad Ecuatoriana de Ortopédia y Traumatología (SEOT)

Merchan G, MD (Hospital de la Policia Nacional)

Asociación Salvadoreña de Ortopédia y Traumatología (ASOT)

Durán Sánchez MA, MD (Instituto Salvadoreño del Seguro Social); Gómez González RA, MD (Hospital Jose Rosales); Romero Guerra CA, MD (Centro de Cirugía de Mínima Invasión Escalón)

Asociación Guatemalteca de Ortopédia y Traumatología (AGOT)

Bolaños R, MD (Hospital Centro Medico); Cahueque M, MD (Hospital Centro Médico); Xicara J, MD (Hospital Nacional de Occidente); Fabian E, MD (Hospital Centro Médico); Davila Mohr C, MD (Hospital Nuestra Señora de El Pilar)

Asociación de Cirugía Ortopédica y Traumatología de Honduras (ACOTH)

Bueso OE, MD (Hospital del Instituto Hondureño de Seguridad Social); Caraccioli W, MD (Hospital Regional del Instituto Hondureño de Seguridad Social); Hernandez G, MD (Hospital

Regional del Instituto Hondureño de Seguridad Social); Minueza T, MD (Hospital Fundación Ruth Paz)
Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT)
Gomez Acevedo JM, MD (Hospital de Especialidades, San Francisco de Asís); López Almejo L, MD (Universidad Autonoma de Coahuila); Padilla Rojas LG, MD (Hospital Puerta de Hierro); Quintero S, MD (Universidad de Guadalajara);
Asociación Nicaraguense de Ortopedia y Traumatología (ANOT)
Castro N, MD (Hospital Carlos Roberto Huembes); Aguilar D, MD (Hospital Metropolitano Vivian Pellas); Garcia Rizo J, MD (Hospital Viviam Pellas); Gutierrez V, MD (Hospital Salud Integral);
Sociedad Panameña de Ortopedia y Traumatología (SPOT)
Garuz M, MD (Hospital Punta Pacífica)
Sociedad Paraguaya de Ortopedia y Traumatología (SPOT)
Segovia J, MD (Instituto de Previsión Seguro)
Sociedad Peruana de Ortopedia y Traumatología (SPOT)
Salce I, MD (Clínica Delgado AUNA); Velit A, MD (Hospital Central de la Fuerza Aerea del Peru)
Sociedad de Ortopedia y Traumatología del Uruguay (SOTU)
Etchegoyen JL, MD (Mutualista Medica Uruguaya); Filomeno P, MD (Instituto Nacional de Ortopedia y Traumatología, Hospital de Clínicas); López JC, MD (Banco de Protesis); Pérez ME, MD (Universidad de la República)**;** Vilensky E, MD (Hospital Policial)
Sociedad Venezolana de Cirugía Ortopédica y Traumatología (SVCOT)
Serrano Fermin AJ, MD (Hospital Vargas de Caracas)
ACTUAR Members
Elias N (Vila Velha Hospital); Estrada Tellez DA, MD (Hospital Civil de Guadalajara); Flores Biard A, MD (Hospital Ángeles del Carmen, Guadalajara); Medina F, MD (Instituto Mexicano del Seguro Social, Hospital de Traumatología, Ortopedia y Rehabilitación Magdalena de las Salinas UMAE DVFN); Mercado Salcedo E (Instituto Mexicano de Seguro Social); MacKechnie MA, MD, CM, FRCSC (MaineGeneral Medical Center, Geisel School of Medicine, Dartmouth College); Madrigal Gutierrez R, MD (Tecnológico de Monterrey, Hospital Puerta de Hierro); Ramirez Guevara C, MD (Hospital Puerta de Hierro Norte)

CHAPTER 9

9

Management of Soft-Tissue Coverage of Open Tibia Fractures in Latin America: Techniques, Timing, and Resources

MacKechnie MC[1], Flores MJ[1], Giordano V[2], Terry MJ[3], Garuz M[4], Lee N[1], Padilla Rojas LG[5], MacKechnie MA[6], Bidolegui F[7], Brown K[1], Quintero JE[8], Ding A[1], Sánchez Valenciano CG[9], Tabares Neyra H[10], Segovia J[11], Aguilar D[12], Van Lieshout EMM[13], Verhofstad MHJ[13], Miclau T[1], Study Group[†]

[1]University of California, San Francisco, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, Department of Orthopaedic Surgery, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[2]Serviço de Ortopedia e Traumatologia Prof Nova Monteiro, Hospital Municipal Miguel Couto, Avenida Bartolomeu Mitre, 1080, Rio de Janeiro, 22793-260 Brazil
[3]Institute for Global Orthopaedics and Traumatology, Division of Plastic and Reconstructive Surgery, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[4]Hospital Santo Tomás, Calle 37 Este, Panamá, Panama
[5]Federación Mexicana de Colegios de Ortopedia y Traumatología A.C, Puerta de Hierro Hospital
[6]Avenida Empresarios 150, Zapopan, Jalisco, 45116, México
Director of Sports Medicine, Department of Orthopaedic Surgery, Cleveland Clinic Martin Health, 200 Hospital Avenue, Stuart, Florida, 34994
Servicio de Ortopedia y Traumatología, Hospital Sirio Libanes, Campana 4658, C1419, Buenos Aires, Argentina
[8]Fracturas y Fracturas, Carrera 12 Bis #9-22, Pereira-Risaralda, Colombia
[9]Centro Médico de Caracas, Avenida Eraso, Plaza El Estanque Urb, Caracas, 1011, Venezuela
[10]Centro de Investigaciones en Longevidad, Envejecimiento y Salud (CITED), Sociedad Cubana de Ortopedia y Traumatologia Calle G y 27, Vedado GP, 10400, La Habana, Cuba
[11]Instituto de Prevision Social, Hospital Central, Avenida Sacramento y Dr Manuel Peña, Asunción, Paraguay
[12]Centro de Ortopedia y Traumatología, Hospital Vivian Pellas, Managua, PO Box 2261, Nicaragua
[13]Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands

Injury. 2022;2(41):1-8

Abstract

Purpose: This study examined soft-tissue coverage techniques of open tibia fractures, described soft-tissue treatment patterns across income groups, and determined resource accessibility and availability in Latin America.

Materials and Methods: A 36-question survey was distributed to orthopaedic surgeons in Latin America through two networks: national orthopaedic societies and the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR). Demographic information was collected, and responses were stratified by income groups: high-income countries (HICs) and middle-income countries (MICs).

Results: The survey was completed by 469 orthopaedic surgeons, representing 19 countries in Latin America (2 HICs and 17 MICs). Most respondents were male (89%), completed residency training (96%), and were fellowship-trained (71%). Only 44% of the respondents had received soft-tissue training. Respondents (77%) reported a strong interest in attending a soft-tissue training course. Plastic surgeons were more commonly the primary providers for Gustilo Anderson (GA) Type IIIB injuries in HICs than in MICs (100% vs. 47%, $p<0.01$) and plastic surgeons were more available (<24 hours of patient presentation to the hospital) in HICs than MICs (63% vs. 26%, $p=0.05$), demonstrating statistically significant differences. In addition, respondents in HICs performed free flaps more commonly than in MICs for proximal third (55% vs. 10%, $p<0.01$), middle third (36% vs. 9%, $p=0.02$), and distal third (55% vs. 10%, $p<0.01$) lower extremity wounds. Negative Pressure Wound Therapy (NPWT or Wound VAC) was the only resource available to more than half of the respondents. Though not statistically significant, surgeons reported having more access to plastic surgeons at their institutions in HICs than MICs (91% vs. 62%, $p=0.12$) and performed microsurgical flaps more commonly at their respective institutions (73% vs. 42%, $p=0.06$).

Conclusion: The study demonstrated that most orthopaedic surgeons in Latin America have received no soft-tissue training, HICs and MICs have different access to plastic surgeons and different expectations for flap type and definitive coverage timing, and most respondents had limited access to necessary soft-tissue coverage surgical resources. Further investigation into differences in the clinical outcomes related to soft-tissue coverage methods and protocols can provide additional insight into the importance of timing and access to specialists.

Introduction

The burden of musculoskeletal disease poses a significant global health challenge, with low-and middle-income countries (LMICs) being particularly affected, resulting in approximately 90% of trauma-related deaths worldwide.[1–3] Open tibial shaft fractures are one of the most frequently reported traumatic injuries, being the most common long bone fracture, and associated with high rates of infection, nonunion, and malunion.[1] Road traffic accidents have contributed to the rise in the incidence of open tibia fractures, which has led to over 50,000 open fractures per year in some Latin American countries, with complication rates reaching as high as 20%.[4,5]

Due to the high-velocity trauma associated with many open tibia fractures, these injuries are often complicated by soft-tissue damage, which can be exacerbated by poor and untimely wound coverage that can lead to further complications including infection, amputation, and death.[6,7] In high-income countries (HICs), these soft-tissue interventions are often delegated to the expertise of plastic surgeons. However, in LMICs there is often a dearth of plastic surgeons available to treat soft-tissue injuries, and therefore these wounds are managed by orthopaedic surgeons or other healthcare providers who often lack sufficient training.[8]

Multiple measures have been suggested to address this gap in the management of soft-tissue injury following open tibia fractures, such as standard of care protocols, academic partnerships, and international soft-tissue coverage training courses.[9] However, these measures are not well documented across Latin America. In a recent study, it was reported that few middle-income countries (MICs) had standard of care protocols or guidelines in place for open fracture treatment in Latin America.[10,11] The current paucity of literature on soft-tissue management for open traumatic wounds in this region poses a significant challenge in identifying needs, comparing treatment strategies, and determining effective solutions across a diverse economic landscape. Thus, the purpose of this study was to examine soft-tissue coverage techniques of open tibia fractures, describe soft-tissue treatment patterns across income groups, and determine resource accessibility and availability in Latin America.

Materials and Methods

A cross-sectional, multi-national survey was conducted between January to July 2021 to identify orthopaedic surgeons' standards of soft-tissue wound care for open tibia fractures and determine areas for further study and improvement. Inclusion criteria included orthopaedic surgeons that treat traumatic injuries in Latin America. There were no exclusion criteria.

The survey consisted of 36 questions and was designed based on a literature review, and further assessed by two fellowship-trained orthopaedic and plastic surgeons (NL and MT). It was then translated into Spanish and Portuguese by three bilingual Latin American orthopaedic surgeons using the back translation method (MG, CSV, and VG).[12] Demographic information was collected, including country of practice, years of experience, subspeciality training, practice environment, and soft-tissue training level. In addition, a needs assessment gauged orthopaedic surgeons' access and availability to various wound care and microsurgical operating room resources and instruments. To optimize the number of survey responses across the region, the survey was distributed through two networks: national orthopaedic societies across Latin America and the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR),[13] an

academic consortium of Latin American orthopaedic trauma surgeons interested in collaborating on clinically-important and regionally-relevant investigative work.

In addition, survey responses were stratified by income groups (HICs and MICs) categorized by the 2021 World Bank Country and Lending Groups[14] data to further evaluate patterns and differences in soft-tissue management of open tibia fractures. Analysis was performed utilizing Fisher's exact tests with $p \leq 0.05$ as the significance level with STATA SE version 17 software (StataCorp). The survey was distributed electronically through REDCap (Research Electronic Data Capture) and the study was deemed exempt from review by the University of California, San Francisco Institutional Review Board.

Results

The survey was completed by 469 orthopaedic surgeons. Respondents represented 19 countries in Latin America (Figure 1), two of which were designated as HICs and 17 as MICs. Most survey respondents were male (89%), completed residency training (96%), and were fellowship-trained (71%). The majority of orthopaedic surgeons practiced in an urban environment (94%), most commonly in a public-private dual practice setting (45%). Most survey respondents (59%) personally treated 20 or fewer open tibia fractures each year. Overall, only 44% of the survey respondents had received soft-tissue training, obtained through surgical mentorship (53%) or formal training courses (47%). Seventy-seven percent of respondents reported a strong interest in attending a soft-tissue training course (Table 1).

Comparison of Soft-Tissue Management between Income Groups

The majority of respondents from both HICs (55%) and MICs (56%) had not received any form of soft-tissue coverage training. Average timing between injury and presentation to the hospital was most commonly reported within 6 hours among HICs and MICs (81.8% vs. 60%, p=0.63), demonstrating no significant difference between income groups. Similarly, timing between presentation to the hospital and the operating room was most commonly reported within 6 hours for both HICs and MICs (64% vs. 63%, p=0.69). Plastic surgeons were identified as the primary providers for soft-tissue coverage for Gustilo Anderson (GA) Type IIIB fractures in HICs significantly more often than in MICs (100% vs. 47%, p<0.01). While not statistically significant, there was a trend of respondents from HICs having access to a plastic surgeon more commonly than in MICs (91% vs. 62%, p=0.12). Additionally, orthopaedic surgeons in HICs reported increased availability to soft-tissue specialists within 24 hours of patient presentation to the hospital in comparison to MICs (63% vs. 26%, p=0.05). Definitive soft-tissue coverage was performed more commonly within seven days in HICs than in MICs (60% vs. 49%, p=0.48) and microsurgical flaps were used more commonly at institutions in HICs than in MICs (72.7% vs. 42.1%, p=0.06), although there were no statistically significant differences between the groups (Table 2).

Preference for soft-tissue management of lower extremity wounds following open tibia fractures were treated significantly differently between income groups. Respondents from HICs performed free flaps more often than in MICs for proximal third (55% vs. 18%, p<0.01), middle third (36% vs. 9%, p=0.02), and distal third lower extremity defects (55% vs. 10%, p<0.01) (Figure 2).

Wound Care and Operating Room Resources

The majority of participants (70%) had access to a Negative Pressure Wound Therapy (NPWT or Wound VAC). Less than half of the participants had access to the following items: magnifying loupes (43%), wall suction outside the OR (41%), manual blade for harvesting skin grafts (Humby blade) (40%), power dermatome (39%), microsurgery instruments (31%), operating microscopes (28%), handheld doppler (22%), and skin graft mesher (19%). Participants reported access to multiple types of dressings, including saline-moistened sterile gauze dressings (76%), occlusive dressings (71%), and anti-microbial dressings (62%). Regarding anti-microbial dressings for wound care, antibiotic ointments were the most commonly accessible (71%), followed by Silvadene (67%), Betadine/Iodine-based dressings (56%), Dakins/Dilute bleach (22%), honey-based dressings (17%), and other supplies (13%) (Table 3).

Discussion

Determining the ideal protocol for open fracture treatment in Latin America is considered one of the top health research priorities in musculoskeletal care,[15] with timeliness and method of treatment being critical to the function and outcome of these injuries.[16,17] This study adds to recent research on open tibia fracture management in Latin America by identifying soft-tissue coverage techniques, timing, and available resources across HICs and MICs.

Countries in Latin America have large disparities in healthcare expenditures in relation to their Gross Domestic Product (GDP) per capita, ranging from 3.5%-11.2%, resembling similar percentages to those observed in low, middle, and high-income countries.[18,19] Socioeconomic factors, as well as diverse national healthcare systems in this region, contribute to the uneven distribution of musculoskeletal trauma care across centers, disproportionately impacting those in resource-limited settings.[6,20–24]

In this study, plastic surgeons in HICs were more commonly cited as the primary providers responsible for performing soft-tissue coverage than in MICs. Of note, a small percentage of respondents reported no access to orthopaedic or plastic surgeons to provide soft-tissue coverage for GA Type IIIB open tibia fractures, likely requiring the patient to be referred to a more well-equipped hospital with access to specialists and resources. Plastic surgeons were also reportedly more accessible in HICs than MICs, consistent with prior literature citing lack of access to specialists as a major barrier to performing wound coverage in LMICs.[6,11,25–28] Indeed, in Latin America, a prior study reported that soft-tissue flaps are not performed in nearly one-third of GA Type IIIB fractures due to these barriers.[25] Although the orthopaedic surgeon-respondents across HICs and MICs in this study received similar levels of soft-tissue training, the greater availability and access to specialist coverage in HICs was associated with timelier definitive treatment (within seven days) than in MICs, supporting the advantages of a combined orthoplastic team. Other barriers that may factor into time to definitive soft-tissue coverage between income groups include individual surgeon expertise, medical cost, implant and equipment availability, hospital resources, and infrastructure.[29]

Multidisciplinary management between orthopaedic and plastic surgery teams is advantageous for the treatment of severe open tibia fractures, as it is associated with timelier treatment, quicker recovery, and less complications.[30–33] Plastic surgeons play a critical role in trauma centers performing limb-saving flap procedures, skin grafts, and microsurgery. Given these benefits, combined specialty teams are recognized in national open fracture treatment guidelines in

Europe and North America.[34–36] Yet, many guidelines in Latin America are neither well-described nor standardized across the region.[20,25] Using evidence-based standardized guidelines, such as the British Association of Plastic Reconstructive and Aesthetic Surgeons (BAPRAS),[36] could help guide the development of regional protocols that include definitive soft-tissue coverage within seven days, "fix and flap" soft-tissue coverage with concomitant definitive fixation, and NPWT as an adjunct to open fracture management, all of which surgeons in HICs and MICs could work towards to improve outcomes and decrease complications.[37] Some principles of lower extremity management outlined in these guidelines, including wound debridement within 24 hours of injury and antibiotic administration within 3 hours of injury for GA Type I-III fractures are already reported as common practice among orthopaedic surgeons in Latin America.[25]

While standard orthopaedic residency training typically does not include soft-tissue flap coverage techniques as part of their core curriculum, this study's findings provide a perspective on current training and practices in this region, which can aid in the development of solutions to address treatment gaps. Efforts to train the orthopaedic surgeons acutely managing open tibia fractures with wound defects has been shown to be a cost-effective way of addressing these complex injuries in lesser-resourced settings.[38,39] Specifically, hands-on reconstructive training courses in these environments led by both orthopaedic and plastic surgeons can augment surgeons' knowledge and skill in managing rotational flaps, skin grafts, and wound management.[9,29,40–42]

Less than half of the study participants reported having access to various instruments in the operating room, including magnifying loupes, wall suction, Humby blades, and power dermatomes. NPWT was the only resource available to the majority of orthopaedic surgeons. Though previously believed to decrease infection rates of severe open wounds, a 2018 Cochrane review and a large randomized controlled trial showed no clear differences in healing or infection rates in open fractures in comparison to conventional dressings.[43,44] While NPWT is widely available in the operating room, this method of wound coverage may not be an adequate substitute to soft-tissue coverage.[45] Further, this survey did not distinguish between industry manufactured and improvised NPWT devices, the latter of which is used in some public hospitals in Latin America and has an efficacy that has not been well described. Additional investigation on the differences between NPWT devices would be beneficial. In HICs, surgeons in Latin America were predisposed to treat lower extremity proximal third, middle third, and distal third defects more commonly with free flaps, likely due to the greater access to plastic surgeons at their institutions. Conversely, surgeons in MICs more commonly treated these injuries with various other methods, including fasciocutaneous flaps, local muscle flaps, or direct wound care. While there is evidence to support that free flaps can lead to less wound complications for fractures with high grade osseus injuries,[46] Cho et al. reported no differences in healing or infection rates between fasciocutaenous and muscle flaps, describing both as adequate methods for wound coverage.[47,48] Though the decision between flap type coverage is dependent on the location and severity of the defect,[37] further examination of the differences in soft-tissue treatment could help to identify areas of change to improve clinical outcomes.

This large-scale multi-national study describes orthopaedic surgeons' soft-tissue coverage techniques of open tibia fractures in Latin America, with the intent to provide insight into region-

specific knowledge gaps. Nineteen countries were represented in this study, providing a broad overview of regional treatment patterns and availability of wound care resources. The study demonstrated that most respondents had limited access to necessary soft-tissue coverage surgical tools and resources, most orthopaedic surgeons in this region have received no soft-tissue training, and HICs and MICs have different access to plastic surgeons and expectations for flap type and timing to definitive coverage.

This study had several limitations. First, a chain-referral sampling method was utilized to improve the number of responses, precluding the ability to estimate a survey response rate. However, this method allowed the survey to be distributed more widely and to a more diverse group of orthopaedic surgeons across the region. Second, the overall number of 469 survey responses was low in comparison to the actual number of practicing orthopaedic surgeons in Latin America, limiting the generalizability of the results. Though it is difficult to provide an absolute number of practicing orthopaedic surgeons across the region, a total of 30,000 orthopaedic surgeon-members have been estimated across 20 Latin American national societies.[25] Nevertheless, the survey represented participants from 19 countries in Latin America, providing for a regional evaluation of soft-tissue treatment techniques. Third, there were few responses collected overall from the HICs, which may not adequately reflect the treatment practices across this entire income group and may affect statistical inferences. These fewer responses are due, in large part, to the fact that there are only two countries designated as HICs in Latin America (Chile and Uruguay); it is valuable, however, to include these data to fully understand management differences in the region.

In summary, this study's findings support the need for soft-tissue training courses, including rotational flaps, skin graft, and wound management, as well as better allocation of surgical tools and resources for orthopaedic surgeons in this region. Further investigation into differences in the clinical outcomes and protocols can provide additional insight into the importance of timing and access to specialists.

Funding
This study was supported by funding from the Wyss Medical Foundation.

References

1. Mock CN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Clin Orthop Relat Res*. 2008;466(10):2306-2316.
2. Moroz PJ, Spiegel DA. The World Health Organization's Action Plan on the Road Traffic Injury Pandemic: Is There Any Action for Orthopaedic Trauma Surgeons? *J Orthop Trauma*. 2014;28(6):4.
3. Hofman K, Primack A, Keusch G, Hyrnkow S. Addressing the Growing Burden of Trauma and Injury in Low-and Middle-Income Countries. *Am J Public Health*. 2005;95(1):13-17.
4. Fraser B. Traffic Accidents Scar Latin America's Roads. *Lancet*. 2005;366(9487):703-704.
5. Orihuela-Fuchs VA, Fuentes-Figueroa S. [Infection Rate in Open Fractures Adjusted for the Degree of Exposure]. *Acta Ortop Mex*. 2013;27(5):293-298.
6. Gosselin R. Injuries: the neglected burden in developing countries. *Bull World Health Orga*. 2009;87(4):246.
7. Carey JN, Caldwell AM, Coughlin RR, Hansen S. Building Orthopaedic Trauma Capacity: IGOT International SMART Course. *J Orthop Trauma*. 2015;29 Suppl 10:17-19.
8. Townley WA, Nguyen DQA, Rooker JC, Dickson JK, Goroszeniuk DZ, Khan MS, et al. Management of Open Tibial Fractures - A Regional Experience. *Ann R Coll Sug Engl*. 2010;(92):693-696.
9. Wu HH, Kushal PR, Caldwell AM, Coughlin RR, Hansen SL, Carey JN. Surgical Management and Reconstruction Training (SMART) Course for International Orthopedic Surgeons. *Ann Glob Health*. 2016;82(4):652-658.
10. Miclau T, Hoogervorst P, Shearer DW, El Naga A, Working Z, Martin C, et al. Current Status of Musculoskeletal Trauma Care Systems Worldwide. *J Orthop Trauma*. 2018;32 Suppl(7):S64-70.
11. Albright PD, MacKechnie MC, Jackson JH, Chopra A, Holler JT, Flores Biard A, et al. Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An Analysis of Participants in an Orthopaedic Surgical Skills Training Course in Mexico. *OTA Int*. 2019;2(4):e044.
12. Brislin RW. Back-Translation for Cross-Cultural Research. *J Cross-Cult Psychol*. 1970;1(3):185-216.
13. Miclau T, MacKechnie MC, Shearer DW, ACTUAR Group. Asociación de Cirujanos Traumatólogos de las Américas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl(7):S8-11.
14. 2021 World Bank and Lending Groups. Accessed October 28, 2021. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
15. Roberts HJ, MacKechnie MC, Shearer DW, Segovia Altieri J, de la Huerta F, Rio MW, et al. Orthopaedic Trauma Research Priorities in Latin America: Developing Consensus Through a Modified Delphi. *J Bone Jt Surg Am*. Published online ePub ahead of print 2021.
16. Cross W III, Swiontkowski MF. Treatment principles in the management of open fractures. *Indian J Orthop*. 2008;42(4):377-386.
17. Hertel R, Lambert SM, Muller S, Ballmer FT, Ganz R. On the timing of soft-tissue reconstruction for open fractures of the lower leg. *Arch Orthop Trauma Surg*. 1999;119(1-2):7-12.
18. Statista. Healthcare expenditure as percentage of GDP in Latin America and the Caribbean in 2019, by country. Accessed October 26, 2021.

https://www.statista.com/statistics/899278/latin-america-health-expenditure-share-gdp-country/
19. OECD iLibrary. Health at a Glance: Latin America and the Caribbean 2020. Accessed October 26, 2021. https://www.oecd-ilibrary.org/sites/6089164f-en/1/3/6/1/index.html?itemId=/content/publication/6089164f-en&_csp_=1ac29f0301b3ca43ec2dd66bb33522eb&itemIGO=oecd&itemContentType=book
20. Padilla Rojas LG, Lopez Cervanted RE, Perez Atanasio JM, Martinez Sanchez M, Gomez Acevedo JM, Kojima KE. Latin America Trauma Systems - Mexico and Brazil. *OTA Int*. 2019;e020:1-6. doi:http://dx.doi.org/10.1097/OI9.0000000000000020
21. Rossiter ND. Trauma - The Forgotten Pandemic? *Int Orthop*.:epub ahead of print. 2021.
22. Arreola-Risa C, Mock CN, Lojero-Wheatly L, de la Cruz O, Garcia C, Canavati-Ayub F, et al. Low-Cost Improvements in Prehospital Trauma Care in a Latin American City. *J Trauma*. 2000;48(1):119-124.
23. Arreola-Risa C, Mock C, Vega Rivera F, Romero Hicks E, Guzmán Solana F, Porras Ramírez G, et al. Evaluating Trauma Care Capabilities in Mexico with the World Health Organization's Guidelines for Essential Trauma Care. *Rev Panam Salud Publica*. 2006;19:94-103.
24. Mock C, Joshipura M, Goosen J, Maier R. Overview of the Essential Trauma Care Project. *Wolrd J Surg*. 2006;30(6):919-929.
25. Albright PD, MacKechnie MC, Roberts HJ, Shearer DW, Padilla Rojas LG, Quintero JE, et al. Open Tibial Shaft Fractures: Treatment Patterns in Latin America. *J Bone Jt Surg*. 2020;00(e1):1-10. doi:http://dx.doi.org/10.2106/JBJS.20.00292
26. Grimes CE, Bowman KG, Dodgion CM, Lavy CB. Systematic Review of Barriers to Surgical Care in Low-Income and Middle-Income Countries. *World J Surg*. 2011;(35):941-950.
27. Ngcelwane M. Expanding the Orthopaedic Training Programme to Improve the Management of Lower Extremity Trauma. *SA Orthop J*. 2015;(14):14-15.
28. Mishra B, Koirala R, Tripathi N, Raj Shrestha K, Adhikary B, Shah S. Plastic Surgery - Myths and Realities in Developing Countries: Experience from Eastern Nepal. *Plast Surg Int*. Published online 2011.
29. Holler JT, Albright P, Challa S, Ali SH, Keys K, et al. Barriers to Performing Soft Tissue Reconstruction Procedures among Orthopedic Surgeons in Low- and Middle-Income Countries: Results of a Surgical Skills Training Course. *Plast Reconstr Surg Glob Open*. 2019;7:e2420-6.
30. Naique SB, Pearse M, Nanchahal J. Management of Severe Open Tibial Fractures: The Need for Combined Orthopaedic and Plastic Surgical Treatment in Specialist Centres. *J Bone Jt Surg Br*. 2006;88(3):351-357.
31. Gopal S, Majumder S, Batchelor AG, et al. Fix and Flap: The Radical Orthopaedic and Plastic Treatment of Severe Open Fractures of the Tibia. *J Bone Jt Surg Br*. 2000;82-B:959-966.
32. Kuripla C, Tornetta P III, Foote CJ, Koh J, Sems A, Shamaa T, et al. Timing of Flap Coverage with Respect to Definitive Fixation in Open Tibia Fractures. *J Orthop Trauma*. 2021;35(8):430-436.
33. VandenBerg J, Osei D, Boyer MI, Gardner MJ, Ricci WM, Spraggs-Hughes A, et al. Open Tibia Shaft Fractures and Soft-Tissue Coverage: The Effects of Management by an Orthopaedic Trauma/Microsurgical Team. *J Orthop Trauma*. 2017;31(6):339-344.

34. *The Management of Skeletal Trauma in the United Kingdom*. British Orthopaedic Association; 1992.
35. American College of Surgeons, Orthopaedic Trauma Association. Best Practices in the Management of Orthopaedic Trauma. Published online 2015:1-38.
36. Nanchahal J, Nayagam S, Khan U, Moran C, Barrett S, Sanderson F, et al. Standards for the Management of Open Fractures of the Lower Limb (British Association of Plastic Reconstructive and Aesthetic Surgeons). In: Royal Society of Medicine Press Ltd; 2009:1-97.
37. Elniel AR, Giannoudis PV. Open Fractures of the Lower Extremity: Current Management and Clinical Outcomes. *EFORT Open Rev*. 2018;3:316-325.
38. Grimes CE, Henry JA, Maraka J, Mkandawire NC, Cotton M. Cost-effectiveness of Surgery in Low-and Middle-Income Countries: A Systematic Review. *World J Surg*. 2014;38(1):252-263.
39. Carlson LA, Slobogean GP, Pollak AN. Orthopaedic Trauma Care in Haiti: A Cost-Effectiveness Analysis of an Innovative Surgical Residency Program. *Value Health*. 2012;15(6):887-893.
40. Challa S, Conway D, Wu Hao Hua, Bisht R, Sherchan B, Lamichhane A, et al. Can a 2-Day Course Teach Orthopaedic Surgeons Rotational Flap Procedures? An Evaluation of Data from the Nepal SMART Course Over 2 Years. *J Orthop Trauma*. 2018;32 Suppl(7):S38-42.
41. Peter NA, Pandit H, Le G Nduhiu M, Moro E, Lavy C. Delivering a Sustainable Trauma Management Training Programme Tailored for Low-Resource Settings in East, Central and Southern Africa Countries Using a Cascading Course. *Injury*. 2016;(47):1128-1134.
42. Singh J, Dhillon MS, Dhatt SS. Single-Stage "Fix and Flap" Gives Good Outcomes in Grade 3B/C Open Tibial Fractures: A Prospective Study. *Malays Orthop J*. 2020;14(1):61-73.
43. Negative Pressure Wound Therapy for Open Traumatic Wounds. *Cochraine Database Syst Rev*. 2018;(7).
44. Costa ML, Achten J, Bruce J, Tutton E, Petrou S, Lamb S, et al. Effect of Negative Pressure Wound Therapy versus Standard Wound Management on 12-Month Disability Among Adults with Severe Open Fracture of the Lower Limb: The WOLFF Randomized Clinical Trial. *JAMA*. 2018;(319):2280-2288.
45. Coles CP. Open Fractures with Soft-Tissue Loss: Coverage Options and Timing of Surgery. *OTA Int*. 2020;3(1):e053-056.
46. Pollak AN, McCarthy ML, Burgess AR. Short-Term Wound Complications after Application of Flaps for Coverage of Traumatic Soft-Tissue Defects about the Tibia. The Lower Extremity Assessment Project (LEAP) Study Group. *J Bone Jt Surg Am*. 2000;82(12):1681-1691.
47. Godina M. Early Microsurgical Reconstruction of Complex Trauma of the Extremities. *Plast Reconstr Surg*. 1986;78(3):285-292.
48. Parikh PM, Hall MM, Attinger CE, Masden DL, Steinberg JS. External Fixation: Indications in Lower Extremity Reconstruction and Limb Salvage. *Plast Reconstr Surg*. 2009;123:160e-161e.

Figure 1. Map of survey respondents by country and identification of income groups (HICs and MICs) determined by the 2021 World Bank Country and Lending Groups data.

Figure 2. Survey respondents' preference for treatment of lower extremity proximal, middle, and distal third defects stratified by income groups (HICs vs. MICs).

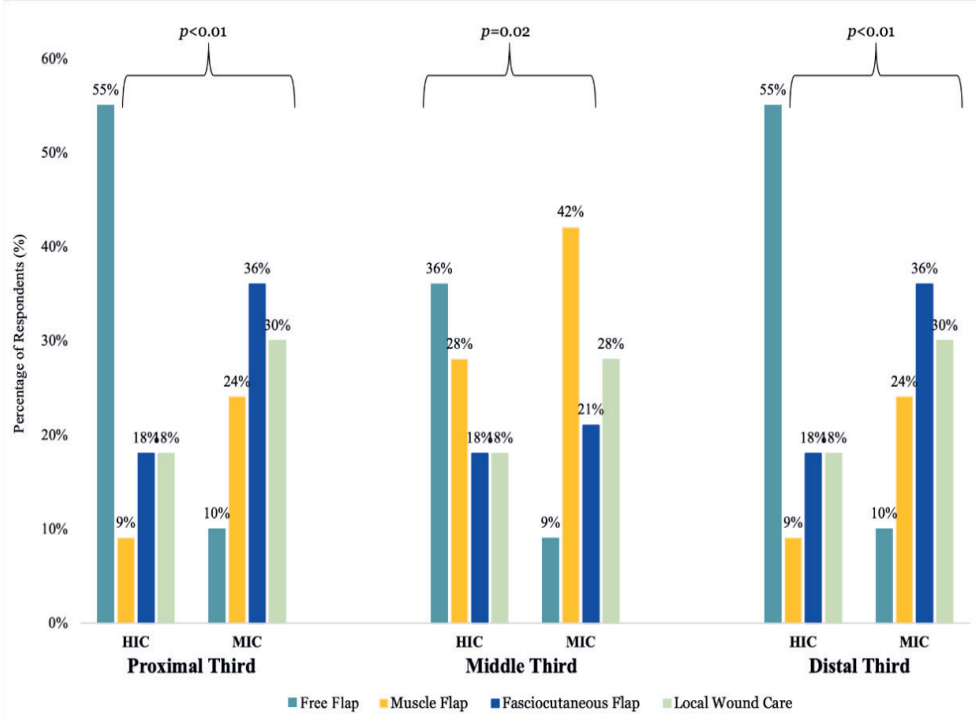


Table 1. Demographic data of survey respondents

	Total n (%) *469 (100)*
Male	416 (88.7)
Years in practice	
0-5	69 (14.7)
6-10	88 (18.8)
11-15	70 (14.9)
16-20	67 (14.3)
>21	175 (37.3)
Residency training	448 (95.7)
Fellowship in musculoskeletal trauma	333 (71.3)
Practice setting	
Public-Private (Combination)	212 (45.2)
Public hospital	126 (26.9)
Private practice	102 (21.7)
Academic practice	28 (6)
Practice location	
Urban	439 (93.6)
Suburban	25 (5.3)
Rural	5 (1.1)
Supervise Residents	285 (60.8)
Received soft-tissue training	
Yes	207 (44.2)
No	262 (55.8)
Type of soft-tissue training	
Surgical mentorship	108 (52.7)
Formal training course	97 (47.3)
Number of open tibia fractures personally treated each year	
0-10	173 (38.1)
11-20	93 (20.5)
21-30	61 (13.4)
31-40	28 (6.2)
41-50	34 (7.5)
51-60	15 (3.3)
61-70	8 (1.8)
71-80	3 (1)
81-90	1 (.2)
91-100	16 (3.1)
>100	8 (1.8)

*Various data not reported by all respondents

Table 2. Comparison of soft-tissue management between income groups

	High-Income Countries N (%)‡	**Middle-Income Countries N (%)‡**	**P Value**
Total	*11 (100)*	*458 (100)*	
Average time between injury and patient presentation to hospital			
<6 hours	9 (81.8)	274 (60)	0.63
24 hours	2 (18.2)	173 (37.9)	
48 hours	0 (0)	10 (2.1)	
Average time between patient presentation and the OR for fracture stabilization			
<6 hours	7 (63.7)	281 (62.5)	0.69
24 hours	4 (36.4)	142 (31.6)	
48 hours	0	27 (6)	
Average time to provide soft-tissue coverage after presentation of injury			
<7 days	6 (60)	194 (48.7)	0.48
>7 days	4 (40)	204 (51.3)	
Primary soft-tissue coverage provider for GA-IIIB fractures			
Plastic surgeon	11 (100)	213 (46.9)	<0.01
Orthopaedic surgeon	0 (0)	205 (45.1)	
No available surgeon	0	36 (7.9)	
How often is a plastic surgeon available at your institution?			
Always	10 (90.9)	282 (61.7)	0.12
Sometimes	1 (9.1)	69 (15.1)	
Never	0 (0)	106 (23.2)	
How available is your soft-tissue coverage provider?			
Inpatient (initial hospitalization) <24 hours	7 (63.6)	118 (26.2)	0.05
Inpatient (initial hospitalization) <1-3 days	3 (27.3)	134 (29.71)	
Inpatient (initial hospitalization) >3 days	1 (9.1)	139 (30.8)	
Transfer or outpatient follow-up only	0	60 (13.3)	
Are microsurgical flaps performed at your institution?			
Yes	8 (72.7)	192 (42.1)	0.06
No	3 (27.3)	264 (57.9)	
Have you received soft-tissue coverage training?			
Yes	5 (45.4)	202 (44.2)	1
No	6 (54.5)	255 (55.8)	
Are you interested in attending a soft-tissue training course?			

Very interested	7 (63.6)	353 (77.2)	0.13
Moderately interested	2 (18.2)	82 (18)	
Not interested	2 (18.2)	22 (4.8)	

*Various data not reported by all respondents
*Tests of significance are completed with Fisher's exact test ($p \leq 0.05$)
‡2021 World Bank Country and Lending Groups

Table 3. Wound care and operating room resources

	Total n (%) *469 (100)*
Which OR resources do you consistently have access to?+	
Negative Pressure Wound Therapy (NPWT or Wound VAC)	328 (69.8)
Magnifying loupes	201 (42.8)
Wall suction outside the OR	192 (40.8)
Manual blade for harvesting skin grafts (e.g Humby blade)	189 (40.2)
Power dermatome	184 (39.1)
Microsurgery instruments	147 (31.3)
Operating microscopes	130 (27.7)
Handheld doppler	103 (21.9)
Skin graft mesher	91 (19.4)
Which dressings do you consistently have access to?+	
Saline-moistened sterile gauze dressing	355 (75.5)
Occlusive dressing	332 (70.6)
Anti-microbial dressing	289 (61.5)
What type of anti-microbial dressings do you have access to?+	
Antibiotic ointments	333 (70.8)
Silvadene	315 (67)
Betadine/Iodine-based dressing	262 (55.7)
Dakins/Dilute bleach	102 (21.7)
Honey-based dressing	82 (17.4)
Other	61 (12.9)
What type of microsurgical instruments are available at your institution?+	
Not sure	270 (57.4)
8-0 suture (nylon, proline)	183 (38.9)
9-0 suture	131 (27.9)
Micro needle-holder	129 (27.4)
Curved micro dissecting scissors	126 (26.8)
Straight micro scissors	122 (26)
Micro-pickups	112 (23.8)
10-0 suture	107 (22.8)
Micro vessel dilator	99 (21.1)

*Various data not reported by all respondents
+Participants were able to select multiple responses

Acknowledgements
†Study Group (Corporate Authors)
Rafael Amadei, MD (Hospital Cuenca Alta Cañuelas, Argentina); Fernando Baldy dos Reis, MD (EPM-UNIFESP); Paulo R. Barbosa Lourenco, MD (Hospital Quinta D'or, Rio de Janeiro, Brazil); Renny Cárdenas Quintero, MD (Sociedad Venezolana de Cirugía Ortopédica y Traumatología, Hospital Central de San Cristóbal); Fernando de la Huerta, MD (Hospital Country 2000); Bibiana Dello Russo, MD (Hospital Nacional de Pediatría, Profesor J.P. Garrahan, Argentina); Igor A. Escalante Elguezabal, MD (Hospital Universitario de Caracas, Venezuela); Robinson Esteves Pires, MD (Universidade Federal de Minas Gerais, Belo Horizonte, Brazil); Diego Abraham Estrada Tellez, MD (Hospital Civil Fray Antonio Alcalde, Mexico); Nicolas Gaggero, MD (Hospital del Trabajador); Germán Garabano, MD (Hospital Británico de Buenos Aires, Buenos Aires, Argentina); Erika Guerrero Rodriguez, MD (Hospital Universitario José Eleutario Gonzalez); Gustavo Hernández Vivas, MD (IHSS, Hospital Fundación Ruth Paz); Jose María Jiménez Avila, MD, PhD (Institute Tecnológico y de Estudios Superiores de Monterrey, Campus Guadalajara, Guadalajara, Jalisco, México); Kodi E. Kojima, MD, PhD (Hospital das Clínicas HCFMUSP, Faculdade de Medicina, Universidade de Sao Paulo, Sao Paulo, Brazil); Leonardo López Almejo, MD (Federación Mexicana de Colegios de Ortopedia y Traumatología A.C, Hospital Star Médica, Aguascalientes, Mexico); Roberto López Cervantes, MD (Hospital de Especialidades San Francisco de Asis); Aramíz López Durán, MD (Instituto Nacional de Pediatria); Gerardo López Mejia, MD (Hospital Christus Muguerza Saltillo); Ricardo Madrigal Gutiérrez, MD (Hospital Puerta de Hierro, Mexico); Jose Martínez Ruíz, MD (Hospital Civil Fray Antonio Alcade, Mexico); Claudia Medina, MD (IPS Universitaria Clinica Leon XIII, Colombia); Edgar E. Mercado Salcedo, MD (Instituto Mexicano del Seguro Social, Mexico); Saúl Mingüer Vargas, MD (Hospital Regional Presidente, Juárez del ISSSTE, Oaxaca, Mexico); Tomás Minueza, MD (Hospital Fundación Ruth Paz); Eduardo Octaviano Navarro Martínez, MD (Hospital General Dr. Aurelio Valdivieso); Maura Ocampo Vega, MD (Hospital General, Regional Número 20, Tijuana BC, México); María Elena Pérez Carrera, MD (Clínica Tramatología y Ortopedia Pediatrica, Universidad de la República Uruguay); César Pesciallo, MD (Hospital Británico de Buenos Aires); Luiz Henrique Penteado da Silva, MD (Clínica IOT e HSVP de Passo Fundo, RS, Brazil); Claudia Ramirez, MD (Puerta de Hierro); Marcelo Rio, MD (Clínica Zabala, Argentina); Jesús Rodriguez López, MD (Centro de Investigación y Docencia en Ciencias de la Salud, Universidad Autonoma de Sinaloa, Mexico); Alberto J Serrano F, MD (Universidad Central de Venezuela, Facultad de Medicina, Escuela de Medicina José María Vargas, Caracas, Venezuela); Santiago Svarzchtein, MD (Centro Médico Integral Fitz Roy, Argentina); Victor Toledo-Infanson, MD (Hospital General Gua Prieta, SSA); Miguel Triana, MD (Fundación Cardioinfantil, Hospital Infantil de San José y Clínica la Colina, Colombia); Jorge Verlarde, MD (Hospital Santo Tomás, Panama); Eduardo Vilensky, MD (CASMUS, Asociación Española, Uruguay); Mauricio Zuluaga, MD (Clínica Imbanaco)

CHAPTER 10

10

Predictors of Clinical Outcomes for Open Tibia Fracture Management Across Latin America: A Prospective Multi-National Study

MacKechnie MC[1], Shearer DW[1], Quintero JE[2], Amadei R[3], Rio M[4], Bidolegui F[5], Madrigal R[6], Segovia J[7], Salazar M[8], Vega Ocampo M[9], O'Marr JM[1], Albright PD[10], Miclau T[1]

[1]Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, Department of Orthopaedic Surgery, University of California, San Francisco, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[2]Fracturas y Fracturas, Pereira-Risaralda, Colombia
[3]Hospital Interzonal General de Agudos, San Martín de la Plata, La Plata, Buenos Aires, Argentina
[4]Ortopedia y Traumatología Clínica Zabala, Buenos Aires, Argentina
[5]Otamendi Sanatorio, Buenos Aires, Argentina
[6]Servicios Médicos Municipales Cruz Verde, Guadalajara, Mexico
[7]Instituto de Prevision Social, Asunción, Paraguay
[8]Hospital Central "Dr. Ignacio Morones Prieto", Monterrey, Mexico
[9]Hospital General, Regional Número 20, Tijuana BC, México
[10]Department of Orthopaedic Surgery, University of Minnesota Medical School, Minneapolis, MN, USA

Abstract

Background: Road traffic accidents (RTAs) are the leading cause of death for young adults aged 5-29 years and also result in non-fatal injuries in 20-50 million people worldwide. Many incur a permanent disability from these injuries, negatively impacting their health-related quality of life (HRQOL). RTAs have contributed to a rise in the incidence of open tibia fractures, particularly in Latin America, a region comprising mostly LMICs, and with the greatest proportion of road traffic fatalities per capita worldwide. The current state of care of open tibia fractures in this region is not well described. Thus, this study sought to identify factors such as severe injury patterns, delayed treatment, and method of fracture stabilization that correlated with decreased HRQOL scores following open tibia fractures in Latin America.

Materials and Methods: A 12-month multi-center prospective observational study was conducted across 16 trauma centers in seven Latin American countries between 2018 to 2022. Inclusion criteria were patients over the age of 18 with isolated AO/OTA type 42 open tibial shaft diaphyseal fractures. Demographic information, medical history, injury characteristics, and treatment patterns were collected during enrollment. The primary outcome measure was the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores using the 12-Item Short Form Health Survey (SF-12), a validated health-related questionnaire that measures patients' physical and mental health status. The SF-12 was administered at the time of enrollment, as well as at the 6, 12, 26, and 52-week post-definitive fixation follow-up timepoints.

Results: Of the total 288 (68.1%) patients that completed the initial enrollment data and follow-up through one-year, less than half (47.2%) received definitive fixation at the time of their initial treatment, with a preference for intramedullary nailing (35.8%), followed by non-operative management using splinting/casting (33.7%) and external fixation (28.1%). Intramedullary nailing was also the most common method (75%) for definitive fixation. Most soft-tissue wounds were closed primarily (88.2%). Gustilo-Anderson (GA) Type II (59.7%) and Type IIIA (22.2%) fractures were most common. The most frequent complications reported were nonunion (6.9%), reoperation (6.3%), superficial infection (5.9%), and deep infection (3.5%). Mean timing from injury to hospital presentation was 3.97 hours (range: 0.15-226.4), hospital presentation to antibiotic administration was 3.46 hours (range: 0.06-481), and hospital presentation to initial surgery was 12.64 hours (range: 0.08-728.1). Most patients (69.1%) received post-operative antibiotics for three or more days. There was a significant negative impact on physical quality of life at one-year post-injury for those that sustained GA Type IIIB fractures (estimate: -6.4, 95% CI (-11.1 – -1.8)) and GA Type IIIC fractures (estimate: -20.7, 95% CI (-30.2 – -11.2)) compared to GA Type I fractures. External fixation (estimate: -3.2, 95% CI (-5.5 – -0.8)) was also associated with lower HRQOL at one-year compared to intramedullary nailing for initial fracture stabilization. There was also a large decrease in mental quality of life for patients that sustained a firearm-related fracture (estimate: -8.5, 95% CI (-14.4 – -2.5) or an OTA arterial score 3 injury (estimate: -16.5, 95% CI (-30.5 – -2.6)). Moreover, delays in timing from injury to hospital (estimate per hour: -0.07, 95% CI (-0.1 – -0.02)) were associated with a decrease in HRQOL and use of external fixation for initial stabilization decreased quality of life at one-year when compared to an intramedullary nail (estimate: -3.0, 95% CI (-5.8 – -0.7).

Conclusion: The results provide insight into the epidemiology, management, and clinical outcomes associated with open tibia fractures in Latin America. Surgeons demonstrated a

preference for staged treatment of open tibia fractures with definitive fixation using intramedullary nails. Delays in timing from patient presentation to the hospital, antibiotic administration, and surgical debridement exist, with a delay in injury to hospital presentation being associated with a decrease in HRQOL. Additionally, more severe fracture patterns (GA Type IIIB and Type IIIC) versus less severe injuries (GA Type I) and initial external fixation use (indicative of more severe injuries) adversely affected patients' HRQOL.

Introduction

Road traffic accidents (RTAs) are the leading cause of death for young adults aged 5-29 years[1] and also result in non-fatal injuries in 20-50 million people worldwide.[2] Many incur a permanent disability from these injuries, negatively impacting their health-related quality of life (HRQOL).[2] Although traumatic injuries including RTAs represent a significant burden globally, mortality and morbidity rates are two-to five-times higher in low and middle-income countries (LMICs) than in high-income countries (HICs).[3,4] Notably, Latin America, a region comprising mostly LMICs, has the greatest proportion of road traffic fatalities per capita worldwide.[5,6] RTIs have contributed to a rise in the incidence of open tibia fractures, which are often associated with severe soft-tissue defects and increased rates of poor outcomes due to complications such as deep infection, chronic osteomyelitis, and nonunion.[7–10] These complications have been shown to have greater negative impact on patients' HRQOL than myocardial infarction, stroke, or end-stage arthritis.[11] Surgeons' early decision-making for open tibia fracture management is critical for optimal long-term outcomes.[12] However, treatment can be particularly challenging in Latin America due to factors including delayed patient presentation,[13] lack of formal guidelines,[14] and limited training opportunities to manage complex issues such as soft-tissue coverage.[15,16] Further, the current state of care of open tibia fractures in this region is not well described in the literature; LMICs remain historically underrepresented in clinical trials,[17–20] with significantly fewer collaborative multi-center publications originating from orthopaedic surgery than from other specialties.[20] Recognizing the need to better understand open tibia fracture management in Latin America, the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR),[21] a consortium of Latin American orthopaedic trauma surgeons interested in building regional research capacity, developed a prospective observational study. It was hypothesized that factors such as severe injury patterns, delayed treatment, and method of fracture stabilization negatively affected HRQOL. This study sought to identify those factors that correlated with decreased HRQOL scores following open tibia fractures in Latin America.

Materials and Methods

A 12-month multi-center prospective observational study was conducted across 16 trauma centers in seven Latin American countries between 2018 to 2022. Inclusion criteria were patients over the age of 18 with isolated AO/OTA type 42 open tibial shaft diaphyseal fractures.[22] Exclusion criteria were patients with a pathologic fracture, a previous deformity or abnormality of the lower limb, patients with previous damage to the same leg that required surgery, one or more additional bone injuries, patients with an injury score according to the Abbreviated Injury Score (AIS) of greater than three (1-minor; 2-moderate; 3-serious; 4-severe; 5-critical; 6-maximal and currently untreatable), a score on the Glasgow Coma Scale (GCS) of less than 12, major burns of greater than 10%, and a spinal cord injury with a neurological deficit. Patients were treated according to the local surgeons' preference at their trauma center. Demographic information, medical history, injury characteristics, and treatment patterns were collected during enrollment.

The primary outcome measures were the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores using the 12-Item Short Form Health Survey (SF-12), a health-related questionnaire that measures patients' physical and mental health status and that has previously been validated in a Latin American country.[23–25] A preoperative SF-12 was administered at the time of enrollment (baseline) and subsequently administered at the 6, 12, 26,

and 52-week post-definitive fixation follow-up timepoints (Figure 1). At each timepoint, patients were evaluated by an orthopaedic trauma surgeon to assess the injury, presence or absence of any complications, and the patients' physical and mental health using the SF-12.

Patients' consent was obtained, and recruitment materials were approved by the Institutional Review Board (IRB) at the central coordinating center, University of California, San Francisco (UCSF), as well as at each participating site. Data was collected at each site by an attending orthopaedic trauma surgeon or research assistant under the surgeon's supervision using Research Electronic Data Capture (REDCap), a secure web-based application used to capture data for clinical research.

Statistical Analysis

All statistical analyses were performed using R (Version 4.2.2). Descriptive statistics were performed to report demographic information, common fracture patterns, and treatment characteristics of all enrolled patients. Univariate analysis was performed using Student's two-tailed T-test and one-way ANOVA for continuous outcomes and the Chi-square test for categorical outcomes. A bivariate analysis was performed for both the PCS and the MCS scores using a one-away ANOVA for all relevant patient factors (i.e. age, gender, Body Mass Index, employment status, comorbidities, alcohol use, and smoking status), injury factors (i.e. mechanism of injury, Gustilo-Anderson classification, timing of injury to hospital presentation, injury to initial antibiotic administration, and injury to initial surgery), and treatment factors (i.e. method of initial and definitive fracture stabilization). Variables found to be significant using an alpha threshold of 0.2 were included in the appropriate multivariable linear regression.

Results

Between 2018 to 2022, 490 patients were screened, of which 423 patients were eligible and consented into the study. In total, 288 (68.1%) patients completed the initial enrollment data and follow-up through one-year (Figure 2). Of these patients who completed the one-year follow-up, the mean age was 34.8 years. The majority were male (84%), employed (70.8%), and held some form of government insurance (55.2%). One quarter (25.3%) of the patients were uninsured and a smaller proportion possessed private insurance (16.6%). The mean pre-injury PCS score was 43.5 and the MCS score was 49.9 (Table 1). The mean one-year post-injury PCS score was 54.7 and the MCS score was 53.3.

The most common fractures reported were Gustilo-Anderson (GA) Type II (59.7%), followed by Type IIIA (22.2%), and Type I (12.5%). GA Type IIIB (4.6%) and Type IIIC (0.7%) fractures were less frequently cited. RTIs were the most common cause of injury (81.9%). Other mechanisms included falls (6.6%), firearms (4.9%), and crush injuries (2.7%). The majority of patients (74.7%) travelled less than 25km for definitive care (Table 2).

Mean timing from injury to hospital presentation was 3.97 hours (range: 0.15-226.4), hospital presentation to antibiotic administration was 3.46 hours (range: 0.06-481), and hospital presentation to initial surgery was 12.64 hours (range: 0.08-728.1). Most patients received antibiotics during their hospitalization (92%), with the majority (69.1%) receiving post-operative antibiotics for three or more days. For soft-tissue defects, simple gauze (56.5%) or saline-soaked gauze (21.6%) were the primary forms of wound bandaging (Table 3).

Less than half of the patients (47.2%) received definitive fixation at the time of their initial treatment. The most common initial treatment was intramedullary nailing (35.8%), followed by non-operative management with splinting/casting (33.7%) and external fixation (28.1%). Regarding definitive fixation, intramedullary nailing was the most common method (75%). Though less common, non-operative splinting/casting (14.2%), external fixation (5.2%), and plating (4.9%) were also reported for definitive fixation. For soft-tissue wounds, most were closed primarily (88.2%) (Table 4).

The most frequent complications reported were nonunion (6.9%), reoperation (6.3%), superficial infection (5.9%), and deep infection (3.5%). These complications were also stratified by GA Type: nonunion (GA Type I: 2.8%, II: 4.6%, IIIA: 12.5%, IIIB: 23.1%, IIIC: 0%), reoperation (GA Type I: 0%, II: 4%, IIIA: 9.4%, IIIB: 30.8%, IIIC: 50%), superficial infection (GA Type I: 0%, II: 8.7%, IIIA: 3.1%, IIIB: 0%, IIIC: 0%), and deep infection (GA Type I: 0%, II: 1.1%, IIIA: 4.7%, IIIB: 30.8%, IIIC: 50%) (Table 5). More than half (58%) of the patients reported returning to work at six months, with 82.2% of patients returning to work at one-year (Table 6).

The one-way ANOVA for the PCS identified the following factors as potential predictors: age, BMI, diabetes status, mechanism of injury, GA classification, all OTA open fracture subcategory classifications (i.e. arterial, wound type, and bone loss), initial form of fixation, and definitive form of fixation. Definitive form of fixation and the OTA open fracture classification were withheld from the model due to collinearity with other predictors. The multivariate model demonstrated no significant sociodemographic relationships. GA Type IIIB fractures (estimate: -6.4, 95% CI (-11.1 – -1.8)) and GA Type IIIC fractures (estimate: -20.7, 95% CI (-30.2 – -11.2)) were associated with large decreases in quality of life at one-year post-injury compared to GA Type I fractures (Table 7). In terms of initial fracture stabilization, external fixation (estimate: -3.2, 95% CI (-5.5 – -0.8)) was associated with lower HRQOL at one-year compared to intramedullary nailing.

The one-way ANOVA for the MCS identified the following factors as potential predictors: BMI, insurance status, alcohol drinking, smoking status, mechanism of injury, OTA open fracture subcategories (i.e. arterial, wound type, and bone loss), injury to hospital time, injury to surgery time, and initial form of fixation. The multivariate model demonstrated a significant protective effect on those that have never smoked (estimate: 3.5, 95% CI (0.74 – 6.3)) on the MCS score at one-year post-injury (Table 8). There was a significant negative impact on quality of life on those that sustained a firearm-related fracture (estimate: -8.5, 95% CI (-14.4 – -2.5) or an OTA arterial score 3 injury (estimate: -16.5, 95% CI (-30.5 – -2.6)). Moreover, a delay in timing from injury to hospital (estimate per hour: -0.07, 95% CI (-0.1 – -0.02)) was associated with a decrease in HRQOL. Finally, external fixation for initial stabilization was associated with a decreased in mental quality of life at one-year when compared to an intramedullary nail (estimate: -3.0, 95% CI (-5.8 – -0.7).

Discussion

In LMICs, open tibia fractures are among the most common and problematic musculoskeletal injuries. These fractures have been designated as “bellwether” injuries, in recognition of their significance for severity and a proxy for traumatic injury volume.[26,27] Even though open tibia

fractures represent a major socioeconomic burden in LMICs, the characteristics and management of these injuries are not well documented. The primary objective of this study was to evaluate the effect of various factors, including severe injury patterns, delayed treatment, and method of fracture stabilization, on patients' HRQOL in Latin America.

Largely due to RTIs, GA Type II and III fractures were most commonly reported in the current study, with over half (59.7%) classifying as Type II and almost one-third (27.6%) classifying as Type III. This stratification of open tibia fracture types were within the ranges reported in studies from lower-resourced regions worldwide,[28] including Argentina and Brazil,[29] Malawi,[30] Tanzania,[31] and Malaysia.[32] In addition to the possibility that the populations may face different mechanisms of injury, there could have been variability in surgeons' open fracture classifications, given that there is an inherent potential for interobserver variations in the GA classification system.[33] The GA Type IIIB and IIIC fractures reported in the current study were associated with significant decreases in HRQOL at one-year post-injury compared to GA Type I fractures. These results were consistent with commonly accepted findings that higher-energy injuries are associated with worse clinical outcomes.[34,35]

Delays in patient presentation to the hospital, antibiotic administration, and initial surgical debridement have all been associated with increased rates of complications,[36] particularly with more severe open fractures. Resultant post-fracture complications have been correlated with poorer patient outcomes.[35] In this study, delays in time from injury to hospital were associated with a decrease in quality of life. The mean time from injury to hospital presentation was 3.97 hours, which was highly variable and represented a delay in care. The variability and greater delays in presentation were particularly interesting, given that most patients lived within 25 kilometers from the treating hospital. These data are consistent with the findings from the International Orthopaedic Multicenter Study in Fracture Care (INORMUS), which determined that Latin American patients with open fractures had the greatest proportion of delays worldwide,[13] with a delay defined by the Lancet Commission on Global Surgery as patient presentation to the hospital being more than two hours post-injury. Although a variable that is difficult to control, the results from this study demonstrate a needed improvement in the consistency of systematic care for patients with these injuries. Further, the delays to initial presentation subsequently affected timeliness of other critical management, including time to initial antibiotic administration and initial surgical procedure (debridement and stabilization).

The mean time from injury to antibiotic administration was 7.44 hours, which was outside of the commonly accepted three-hour recommendation following an open tibia fracture.[36,37] However, the mean time from hospital presentation to antibiotic administration was 3.46 hours, representing another potentially modifiable delay in care. Most patients received antibiotics during their hospitalization (92%), though it was not clear why a minority of patients did not ever receive antibiotics. The general trend for patients with GA Types I and II fractures was to receive gram positive coverage, with GA Type III fractures receiving gram negative coverage, consistent with published recommendations.[38,39] Additionally, the majority of patients (69.1%) received antibiotics for three or more days post-operatively, which was similarly reported for the treatment of GA Types I, II, and III by orthopaedic trauma surgeons in Cuba.[40] This practice may be secondary to their attempts to compensate for delays in pre- or intra-hospital care or wound closure, relative to practices in better-resourced environments where recommended post-

operative antibiotic administration times are trending towards 24 hours, particularly for post-closure wounds.[36] Further, the mean time from hospital admission to initial surgical procedure was 12.64 hours, which is near the 12-hour threshold associated with a 1.5-fold increase in infection compared to patients debrided within six hours,[35] however, it is still within the 24-hour rule recommended as acceptable by others.[41,42] This delay to initial surgery is greater than the 6.8 hours cited in a recent prospective study investigating the epidemiology of 57 open tibia fractures across seven centers in Argentina and Brazil.[29] The discrepancy in timing may be due to the current study's larger sample size and level of variability in resource availability, type of trauma centers, and ranges in standard of care.

Most patients (52.7%) had two or more procedures, with the fractures largely receiving an intramedullary nail, splint/cast, and external fixation on initial management. Intramedullary nails were used preferentially for definitive fixation, consistent with recommendations in the literature for the treatment of tibial shaft fractures,[43,44] with temporary external fixation and a splint/cast frequently used as temporary fixation prior to conversion to a nail. This practice was consistent with those results described in a study by Bhandari et al., suggesting that orthopaedic trauma surgeons preferred intramedullary nailing to external fixators, but this preference progressively declined as the severity of the soft-tissue injury increased.[45] The current study identified a negative correlation between use of external fixation for initial stabilization and patients' MCS score at one year, likely reflecting that more severe injuries were treated initially with external fixation. Finally, a majority of wounds were closed primarily (88.2%), with a minority being treated with delayed primary closure. This is likely reflective of few GA Type IIIB (4.6%) and IIIC (0.7%) fractures, which require additional soft-tissue management and types of dressings available. Gauze (56.5%), saline-soaked gauze (21.6%), and betadine-based (8.6%) dressings were used most commonly, which is consistent with another study's results on the available resources and management of soft-tissue coverage following open tibia fractures in Latin America.[15]

Although suffering from an open tibia injury can have a profound impact on the patient and family's socioeconomic health,[46,47] more than half (58%) of the patients returned to work at six months, with the majority (82.2%) returning at one year. These results are similar to a systematic review summarizing the economic burden of open tibia fractures worldwide, determining that 60% of patients returned to work full-time at one-year.[48] Rates in Argentina and Brazil showed a higher percentage (70.6%) returning to work at four months.[29]

To date, this study represents the largest prospective multi-center, multi-national study evaluating open tibia fracture management in Latin America. In addition to evaluating the effects of a variety of factors on HRQOL, it provided an epidemiological overview of open tibia fractures in Latin America. Strengths of the study included the patient sample size, number of participating sites, and diversity of countries represented throughout the region. Additionally, the follow-up rate at one-year (68.1%) is notable; not only was this study on trauma patients, where it is more difficult to initially screen for their ability to follow-up, but this was also conducted during the COVID-19 pandemic, which, in some cases, limited outpatient clinic availability and patients' willingness to come to a healthcare facility post-operatively. The high rate of follow-up also supports the feasibility of engaging in such investigative work in Latin America.

There were many potential limitations in this study. First, despite the relatively high follow-up rates at one-year, there were still patients lost to follow-up, with some sites being more prone to lack of follow-up than others. Because the study was initiated pre-pandemic and carried through post-pandemic, many of the patients who might normally have returned for in-person follow-up appointments required telephone interviews instead. Telephone interviews with completion of the SF-12 survey were utilized in this study, and though this method has been recognized as an effective method in the field of orthopaedic trauma,[49,50] it could have affected patients' responses. According to a non-orthopaedic study, mental scores were reportedly higher when completing the SF-12 through a telephone interview rather than a written self-assessment.[51] Second, while the site Principal Investigators (PI) received personalized training for data collection and entry, and these data were reviewed for errors throughout the study (MM/TM), it is possible that there were some errors as well as underreporting, such as for complications, although there was no indication that this occurred. Further, complications such as nonunion, deep infection, and malunion were not pre-defined for the surgeons treating the patients, leaving that designation to their own definition. Finally, the sites had varying numbers of patients entered into the study, potentially biasing the results towards those centers and treatment practices that enrolled more patients.

In summary, the results from the current work represent a large-scale, collaborative effort to evaluate injury and treatment factors for open tibia fractures on HRQOL in Latin America. The results further provide insight into the epidemiology, management, and clinical outcomes associated with open tibia fractures in this region. The results of the study showed that the injury characteristics were similar to those in other lower-resourced regions and treatment patterns are consistent with previously reported management throughout Latin America. Further, delays in timing from patient presentation to the hospital, antibiotic administration, and surgical debridement exist, all of which are potentially modifiable factors. In addition, more severe fracture patterns (GA Type IIIB and Type IIIC) versus less severe injuries (GA Type I) and initial external fixation use (indicative of more severe injuries) adversely affected HRQOL. Finally, the success of the study demonstrates the feasibility of conducting collaborative clinical research studies in Latin America.

References

1. WHO. World Health Organization. Global Status Report on Road Safety: Time for Action. Geneva: World Health Organization. Published online 2015. Accessed December 19, 2020. https://apps.who.int/iris/bitstream/handle/10665/44122/9789241563840_eng.pdf;jsessionid=52695470F483BBEB25BFC5685C7FDC04?sequence=1.
2. WHO. Road Traffic Injuries. World Health Organization. Geneva 2018. http://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries
3. Mock CN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Orthop Relat Res*. 2008;466(10):2306-2316.
4. Chen S, Kuhn M, Prettner K, Bloom DE. The Global Macroeconomic Burden of Road Injuries: Estimates and Projections for 166 Countries. *The Lancet*. 2019;3:e390-8.
5. World Health Organization. Global Status Report on Road Safety: Time for Action. *Geneva World Health Organ*. Published online 2009. http://www.who.int/violence_injury_prevention/road_safety_status/report/cover_and_front_matter_en.pdf
6. Fraser B. Traffic Accidents Scar Latin America's Roads. *Lancet*. 2005;366(9487):703-704.
7. Rajasekaran S, Devendra A, Ramesh P, Dheenadhayalan J, Kamal CA. Initial Management of Open Fractures. In: *Rockwood and Green's Fractures in Adults*. Vol 1. Ninth. Wolters Kluwer; :484-530.
8. Kohlprath R, Assal M, Uckay I et al. [Open Fractures of the Tibia in the Adult: Surgical Treatment and Complications]. *Rev Med Suisse*. 2011;7(322):2482-2488.
9. Harris AM, Althausen PL, Kellam J, et al. Complications Following Limb-Threatning Lower Extremity Trauma. *J Orthop Trauma*. 2009;23(1):1-6.
10. Barei DP, Nork SE, Mills WJ, et al. Complications Associated with Internal Fixation of High-Energy Bicondylar Tibial Plateau Fractures Utilizing a Two-Incision Technique. *J Orthop Trauma*. 2004;18(10):649-657.
11. The Devastating Effects of Tibial Nonunion on Health-Related Quality of Life. *J Bone Jt Surg Am*. 2013;95(24):2170-2176.
12. Court-Brown CM, Rimmer S, Prakash U, et al. The Epidemiology of Open Long Bone Fractures. *Injury*. 1998;29:529-534.
13. Pouramin P, Chuan SL, Busse JW, Sprague S, Devereaux PJ, Jagnoor J, et al. Delays in Hospital Admissions in Patients with Fractures Across 18 Low-Income and Middle-Income Countries (INORMUS): A Prospective Observational Study. *The Lancet*. 2020;8:e711-20.
14. Albright PD, MacKechnie MC, Roberts HJ, Shearer DW, Padilla Rojas LG, Quintero JE, et al. Open Tibial Shaft Fractures: Treatment Patterns in Latin America. *J Bone Jt Surg*. 2020;00(e1):1-10. doi:http://dx.doi.org/10.2106/JBJS.20.00292
15. MacKechnie MC, Flores MJ, Giordano V, Terry MJ, Garuz M, Lee N, et al. Management of Soft-Tissue Coverage of Open Tibia Fractures in Latin America: Techniques, Timing, and Resources. *Injury*. 2022;53(4):1422-1429.
16. Albright PD, MacKechnie MC, Jackson JH, Chopra A, Holler JT, Flores Biard A, et al. Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An Analysis of Participants in an Orthopaedic Surgical Skills Training Course in Mexico. *OTA Int*. 2019;2(4):e044.
17. Evaniew N, Godin K, Schemitsch EH, Bhandari M. Evidence Gaps in the Global Decade of Road Traffic Safety. *J Orthop Trauma*. 2014;28(6):S15-7.

18.Moraes VY, Belloti JC, Faloppa F, Bhandari M. Collaborative Multicenter Trials in Latin America: Challenges and Opportunities in Orthopedic and Trauma Surgery. *Sao Paulo Med J*. 2013;131(3):187-192.
19.Schade AT, Hind J, Khatri C, Metcalfe AJ, Harrison WJ. Systematic Review of Patient Reported Outcomes from Open Tibia Fractures in Low and Middle Income Countries. *Injury*. 2020;51(2):142-146.
20.Brophy RH, Smith MV, Latterman C, Jones MH, Reinke EK, Flanigan DC, etc. Multi-Investigator Collaboration in Orthopaedic Surgery Research Compared to Other Medical Fields. *J Orthop Res*. 2012;30(10):1523-1528.
21.Miclau T, MacKechnie MC, Shearer DW, ACTUAR Group. Asociación de Cirujanos Traumatólogos de las Américas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl(7):S8-11.
22.Kazley J, Jahangir A. Tibia Diaphyseal Fracture. In: *StatPearls*. StatPearls Publishing; 2022:1-8. https://www.ncbi.nlm.nih.gov/books/NBK537173/
23.Camelier AA. [SF-12 Health Related Quality of Life in COPD Patients: A Population-Based Study in São Paulo-SP]. Published online 2004:151.
24.Turner-Bowker D, Hogue SJ. Short Form 12 Health Survey (SF-12). In: *Encyclopedia of Quality of Life and Well-Being Research*. Springer; 2014.
25.Ware J, Jr., Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity. *Med Care*. 1996;34(3):220-233.
26.O'Neill KM, Greenberg SLM, Cherian M, et al. Bellwether Procedures for Monitoring and Planning Essential Surgical Care in Low- and Middle-Income Countries: Caesarean Delivery, Laparotomy, and Treatment of Open Fractures. *World J Surg*. 2016;40(11):2611-2619.
27.Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, Ameh EA,et al. Global Surgery 2030: Evidence and Solutions for Achieving Health, Welfare, and Economic Development. *The Lancet*. 2015;386(9993):569-624. doi:10.1016/S0140-6736(15)60160-X
28.Papakostidis C, Kanakaris NK, Pretel J, Faour O, Morell DJ, Giannoudis PV, et al. Prevalence of Complications of Open Tibial Shaft Fractures Stratified as per the Gustilo-Anderson Classification. *Injury*. 2011;42(12):1408-1415.
29.Belangero WD, Fogagnolo F, Kojima KE, Chohfi de Miguel G, Bidolegui F, Bertune AD, et al. Isolated Open Tibial Shaft Fracture: A Seven-Hospital, Prospective Observational Study in Two Latin America Countries. *Rev Col Bras Cir*. 2022;49(e20223301):1-15.
30.Mwafulirwa K, Munthali R, Ghosten I, Schade A. Epidemiology of Open Tibia Fractures Presenting to a Tertiary Referral Centre in Southern Malawi: A Retrospective Study. *Malawi Med J*. 2022;34(2):118-122.
31.Cortez A, Urva M, Haonga B, Donnelley CA, von Kaeppler EP, Roberts HJ, et al. Outcomes of Intramedullary Nailing and External Fixation of Open Tibial Fractures: Three to Five-Year Follow-Up of a Randomized Clinical Trial. *J Bone Jt Surg Am*. 2022;104(21):1877-1885.
32.Yusof NM, Khalid KA, Zulkifly AH, Zakaria Z, Amin MAM, Awang MS, et al. Factors Associated with the Outcome of Open Tibial Fractures. *Malays J Med Sci*. 2013;20(5):47-53.
33.Horn BD, Rettig ME. Interobserver Reliability in the Gustilo and Anderson Classification of Open Fractures. *J Orthop Trauma*. 1993;7(4):357-360.
34.Higgins R, Palmer J, Qureshi AA, Hancock NJ. Patient Reported Outcomes after Definitive Open Tibial Fracture Management. *Injury*. 2022;53(11):3838-3842.
35.Foote CJ, Tornetta P, Reito A, Al-Hourani K, Schenker M, Bosse M, et al. A Reevaluation of the Risk of Infection Based on Time to Debridement in Open Fractures: Results of the

GOLIATH Meta-Analysis of Observational Studies and Limited Trial Data. *J Bone Jt Surg*. 2021;(103):265-273.
36.Mundi R, Chaudhry H, Niroopan G, Petrisor B, Bhandari M. Open Tibial Fractures: Updated Guidelines for Management. *JBJS Rev*. 2015;3(2):e1-7.
37.Patzakis MJ, Wilkins J. Factors Influencing Infection Rate in Open Fracture Wounds. *Clin Orthop Relat Res*. 1989;243(243):36-40.
38.Melvin JS, Dombroski DG, Torbert JT, Kovach SJ, Estherhai JL, Mehta S. Open Tibial Shaft Fractures: I. Evaluation and Initial Wound Management. *J Am Acad Orthop Surg*. 2010;18(1):10-19.
39.Patzakis MJ, Harvey JP, Ivler D. The Role of Antibiotics in the Management of Open Fractures. *J Bone Jt Surg Am*. 1974;56(3):532-541.
40.MacKechnie MC, Albright PD, Tabares Saez H, Tabares Neyra H, Materno Parra Y, Pancorbo Sandoval E, et al. Management of Open Tibial Fractures in Cuba. *Rev Cuba Ortop Traumatol*. 2021;35(2):e405-30.
41.Nicolaides M, Vris A, Heidari N, Bates P, Pafitanis G. The Effect of Delayed Surgical Debridement in the Management of Open Tibial Fractures: A Systematic Review and Meta-Analysis. *Diagnostics*. 2021;11(1017):1-16.
42.Tahir M, Ahmed N, Shaikh SA, Jamali AR, Choudry UK, Khan S. Delay in Initial Debridement for Open Tibial Fractures and Its Possible Impact on Patient Outcomes: A Single-Center Prospective Cohort Study. *J Bone Jt Surg*. 2021;(e20):1-7.
43.Foote CJ, Guyatt GH, Vignesh KN, et al. Which Surgical Treatment for Open Tibial Shaft Fractures Results in the Fewest Reoperations? A Network Meta-Analysis. *Clin Orthop*. 2015;473(7):2179-2192.
44.Henley MB, Chapman JR, Agel J, Harvey EJ, Whorton AM, Swiontkowski MF. Treatment of Type II, IIIA, and IIIB Open Fractures of the Tibial Shaft: A Prospective Comparison of Unreamed Interlocking Intramedullary Nails and Half-Pin External Fixators. *J Orthop Trauma*. 1998;12(1):62-68.
45.Bhandari M, Guyatt GH, Swiontkowski MF, Tornetta P, Hanson B, Weaver B, et al. Surgeons' Preferences for the Operative Treatment of Fractures of the Tibial Shaft: An International Survey. *J Bone Jt Surg Am*. 2001;83(11):1746-1752.
46.O'Hara NN, Mugarura R, Potter J, Stephens T, Rehavi MM, Francois R, et al. Economic Loss Due to Traumatic Injury in Uganda: The Patient's Perspective. *Injury*. 2015;47(5):1098-1103.
47.Holler JT, MacKechnie MC, Albright PD, Morshed S, Shearer DW, Terry MJ. The Impact of Inadequate Soft-Tissue Coverage Following Severe Open Tibia Fractures in Tanzania. *PRS Glob Open*. 2020;8(12):1-8.
48.Schade AT, Khatri C, Nwankwo H, Carlos W, Harrison WJ, Metcalfe AJ. The Economic Burden of Open Tibia Fractures: A Systematic Review. *Injury*. 2021;52:1251-1259.
49.Sathiyakumar V, Apfeld JC, Obremskey WT, Thakore RV, Sethi MK. Prospective Randomized Controlled Trial Using Telemedicine for Follow-Ups in an Orthopaedic Trauma Population: A Pilot Study. *J Orthop Trauma*. 2015;29(3):e139-45.
50.Rauer T, Scherer J, Staubli P, Gerber J, Pape HC, Heining SM. Satisfaction with Telemedicine in Patients with Orthopaedic Trauma During the COVID-19 Lockdown: Interview Study. *JMIR Form Res*. 2022;6(9):e35718-35722.
51.Lungenhausen M, Lange S, Maier C, Schaub C, Trampisch HJ, Endres HG. Randomised Controlled Comparison of the Health Survey Short Form (SF-12) and the Graded Chronic

Pain Scale (GCPS) in Telephone Interviews versus Self-Administered Questionnaires. Are the Results Equivalent? *BMC Med Res Methodol*. 2007;(7):50.

Figure 1. Flow diagram of data collection timepoints

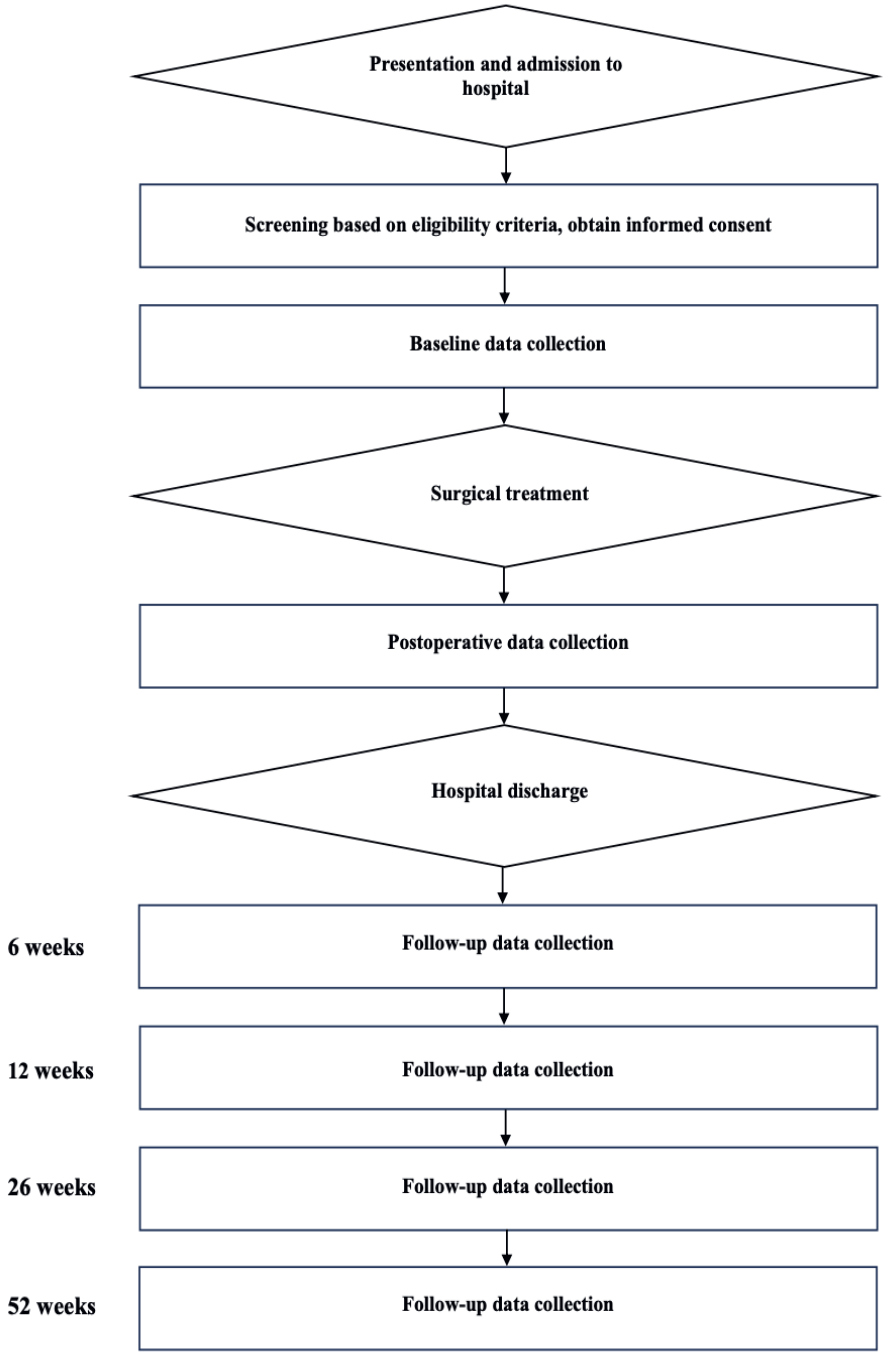


Figure 2. Flow diagram of patient enrollment

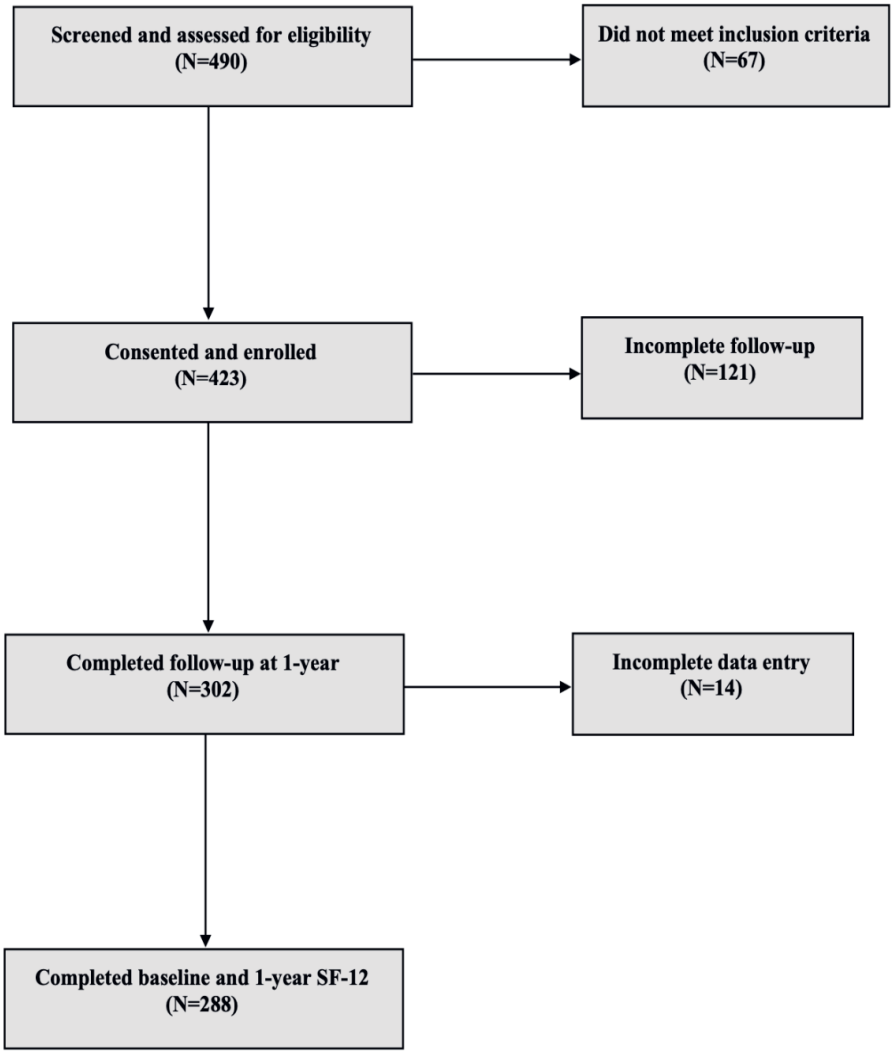


Table 1. Demographics

Characteristic	**Total N=288 N(%)**
Age: mean ± SD	34.8 ± 13.5
Sex (male)	242 (84.0)
BMI: mean ± SD	25.6 ± 3.5
Education	
None	4 (1.4)
Preschool	5 (1.7)
Primary	25 (8.7)
Secondary	162 (56.3)
University	85 (29.5)
Not reported	7 (2.4)
Insurance status	
Government	169 (55.2)
Uninsured	73 (25.3)
Private	48 (16.6)
Not reported	10 (2.7)
Employment	
Working	204 (70.8)
Not working	72 (25.0)
Not reported	12 (4.2)
Diabetes	
Yes	12 (4.2)
No	276 (95.8)
Drinks Alcohol	
Yes	158 (54.9)
No	125 (43.4)
Not reported	5 (1.7)
Smoking Status	
Yes	62 (21.5)
Former	56 (19.4)
Never	170 (59.0)
Pre-Injury SF-12 Score	
PCS	43.5 (11.9)
MCS	49.9 (8.4)
1-year Post-Injury SF-12 Score	
PCS	54.7 (6.5)
MCS	53.3 (7.8)

Table 2. Fracture characteristics

Characteristic	**Total N=288 N(%)**
Gustilo-Anderson Fracture Classification	
Type I	36 (12.5)
Type II	172 (59.7)
Type IIIA	64 (22.2)
Type IIIB	13 (4.6)
Type IIIC	2 (0.7)
Not reported	1 (0.3)
OTA Type	
Skin	
1	261 (90.6)
2	15 (5.2)
3	9 (3.1)
Not reported	3 (1.0)
Muscle	
1	194 (67.3)
2	86 (29.9)
3	3 (1.0)
Not reported	5 (1.7)
Arterial	
1	276 (95.8)
2	9 (3.1)
3	1 (0.3)
Not reported	2 (0.7)
Contamination	
1	126 (43.8)
2	142 (49.3)
3	17 (5.9)
Not reported	3 (1.0)
Bone Loss	
1	263 (91.3)
2	16 (5.6)
3	5 (1.7)
Not reported	4 (1.4)
Mechanism of Injury	
Road traffic incident	236 (81.9)
Fall	19 (6.6)
Firearm	14 (4.9)
Crush	6 (2.7)
Other	12 (4.0)
Hospital Distance	
0-25 km	215 (74.7)
25-50 km	38 (13.2)

50-100 km	16 (5.6)
75-100 km	7 (2.4)
>100 km	9 (3.1)
Not reported	3 (1.0)

Table 3. Open fracture management

Characteristic	**Total N=288 N(%)**
Antibiotics Administered	
Yes	265 (92.0)
No	22 (7.6)
Not reported	1 (0.4)
Antibiotic Regimen †	
1st Gen Cephalosporin	207 (71.9)
3rd Gen Cephalosporin	77 (26.7)
Metronidazole	44 (15.3)
Aminoglycoside	42 (14.6)
Vancomycin	2 (0.7)
Piperacillin/Tazobactam	1 (0.3)
Other	8 (2.8)
Antibiotics Delivery Time Post-Op	
None	3 (1.0)
24 hours	21 (7.3)
48 hours	26 (9.0)
72 hours	36 (12.5)
>72 hours	199 (69.1)
Timing	
Mean hours from injury to hospital presentation (range)	3.97 (0.15-226.4)
Mean hours from injury to antibiotic administration (range)	7.44 (0.7- 484)
Mean hours from hospital presentation to antibiotic administration (range)	3.46 (0.06-481)
Mean hours from injury to initial surgery (range)	16.97 (0.7-729.5)
Mean hours from hospital presentation to initial surgery (range)	12.64 (0.08-728.1)
Wound Treatment	
Gauze	170 (56.5)
Saline-soaked gauze	65 (21.6)
Betadine gauze	26 (8.6)
Chlorhexidine gauze	4 (1.3)
Microdacyn gauze	5 (1.7)
Other	31 (10.3)
NSAID - Pain Control	
Yes	197 (68.4)

†Multiple responses reported

Table 4. Operative treatment

Characteristic	**Total N=288 N(%)**
Definitive Initial Operation	
Yes	136 (47.2)
No	152 (52.7)
Initial Fixation	
Intramedullary nail	103 (35.8)
Splint/Cast	97 (33.7)
External fixation	81 (28.1)
Plate	4 (1.4)
Screws	1 (0.3)
Sarmiento	1 (0.3)
Definitive Fixation	
Intramedullary nail	216 (75.0)
Splint/Cast	41 (14.2)
External fixation	15 (5.2)
Plate	14 (4.9)
Sarmiento	1 (0.3)
Primary Closure	
Yes	254 (88.2)
No	26 (9.0)
Not reported	8 (2.8)

Table 5. Complications

	Total N=288 N(%)	**N=36**	**N=173**	**N=64**	**N=13**	**N=2**
Gustilo-Anderson Classification		**I**	**II**	**IIIA**	**IIIB**	**IIIC**
Nonunion	20 (6.9)	1 (2.8)	8 (4.6)	8 (12.5)	3 (23.1)	0 (0)
Reoperation	18 (6.3)	0 (0)	7 (4)	6 (9.4)	4 (30.8)	1 (50)
Superficial infection	17 (5.9)	0 (0)	15 (8.7)	2 (3.1)	0 (0)	0 (0)
Deep infection	10 (3.5)	0 (0)	2 (1.1)	3 (4.7)	4 (30.8)	1 (50)
Malunion	9 (3.1)	0 (0)	6 (3.5)	2 (3.1)	1 (7.7)	0 (0)
Delayed wound healing	5 (1.7)	0 (0)	1 (0.6)	1 (1.6)	3 (23.1)	0 (0)
Implant failure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Other	4 (1.4)	0 (0)	1 (0.6)	3 (4.7)	0 (0)	0 (0)

Table 8. Return to work

Characteristic	**Total N=288** **N (%)**
Time to return to work	
6 weeks	15 (5)
12 weeks	41 (15)
26 weeks	150 (58)
52 weeks	211 (82.2)

Table 7. SF-12 Physical Component Score (PCS) multivariate linear regression output

Variable	Point Estimate	P Value	95% CI
Age	-0.01	0.72	(-0.08 - 0.05)
BMI	-0.08	0.53	(-0.32 - 0.17)
Diabetes			
Yes	--	--	--
No	1.7	0.42	(-2.5 - 5.9)
Unknown	6.1	0.22	(-3.6 – 15.9)
Mechanism of Injury			
Road traffic incident	--	--	--
Fall	-0.65	0.70	(-3.9 - 2.6)
Crush injury	0.9	0.76	(-4.9 - 6.7)
Firearm injury	1.7	0.45	(-2.7 – 6.1)
Other injury method	3.8	0.12	(-1.0 - 8.6)
Gustilo-Anderson Classification			
GA Type I	--	--	--
GA Type II	-0.43	0.75	(-3.1 - 2.2)
GA Type IIIA	-0.61	0.70	(-3.7 - 2.5)
GA Type IIIB	-6.4	0.01	(-11.1 - -1.8)
GA Type IIIC	-20.7	0.00	(-30.2 - -11.2)
Initial Fixation			
Intramedullary nailing	--	--	--
External fixation	-3.2	0.01	(-5.5 - -0.8)
Plate	0.18	0.96	(-6.5 - 6.8)
Cast only	-2.1	0.06	(-4.3 - 0.1)
Screws	-9.3	0.14	(-21.9 – 3.1)
Sarmiento	-0.03	0.95	(-12.6 – 12.5)

*Categorical variables have their comparator variable listed in parentheses
**Baseline levels are marked with "--"

Table 8. SF-12 Mental Component Score (MCS) multivariate linear regression output

Variable	Point Estimate	P Value	95% CI
BMI	-0.12	0.43	(-0.43 - 0.18)
Drinks Alcohol			
No	--	--	--
Yes	-1.3	0.23	(-3.3 - 0.79)
Smoking Status			
Yes	--	--	--
Former smoker	2.2	0.16	(-0.9 – 5.4)
Never smoker	3.5	0.01	(0.74 – 6.3)
Insurance Type			
Private	--	--	--
Government insurance	-0.54	0.72	(-3.6 - 2.5)
Uninsured	2.0	0.24	(-1.2 – 5.2)
Mechanism of Injury			
Road traffic incident	--	--	--
Fall	0.26	0.90	(-4.0 - 4.5)
Crush injury	2.6	0.78	(-6.5 – 8.6)
Firearm injury	-8.5	0.006	(-14.4 - -2.5)
Other injury method	1.2	0.66	(-4.2 – 6.5)
OTA Class			
OTA arterial, wound, bone loss - score 1	--	--	--
OTA arterial – score 2	1.3	0.65	(-4.5 - 7.2)
OTA arterial – score 3	-16.5	0.02	(-30.5 - -2.6)
OTA wound – score 2	0.32	0.78	(-1.9 - 2.6)
OTA wound – score 3	-2.7	0.26	(-7.2 – 1.9)
OTA bone loss – score 2	-2.4	0.28	(-6.8 - 1.9)
OTA bone loss - score 3	-1.4	0.76	(-10.6 - 7.7)
Hours from Injury to Surgery	0.01	0.42	(-0.01 – 0.001)
Hours from Injury to Hospital	-0.07	0.01	(-0.1 - -0.02)
Initial Fixation			
Intramedullary nail	--	--	--
External fixation	-3.0	0.04	(-5.8 - -0.76)
Plate	5.8	0.12	(-1.9 - 13.12)
Cast only	-1.5	0.28	(-4.4 - 0.67)
Screws	2.5	0.72	(-11.4 - 16.5)
Sarmiento	-0.61	0.93	(-14.5 - 13.2)

*Categorical variables have their comparator variable listed in parentheses
**Baseline levels are marked with "--"

PART IV

Open Tibial Shaft Fractures: Interventions

CHAPTER 11

11

Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An Analysis of Participants in an Orthopaedic Surgical Skills Training Course in México

Albright PD[1], MacKechnie MC[1], Jackson JH[1], Chopra AM[1], Holler J[1], Flores Biard A[2], Padilla Rojas LG[3], Morshed S[1], Miclau T[1], Shearer DW[1], Terry MJ[1]

[1]Institute for Global Orthopaedics and Traumatology, University of California, San Francisco, San Francisco, CA, USA
[2]Hospital Ángeles del Carmen, Guadalajara, Mexico
[3]Centro Médico Puerta de Hierro Especialidades, Zapopan, Mexico

OTA Int. 2019;2(4):e44-9

Abstract

Background: An increasing number of traumatic injuries in low- and low-middle-income countries (LICs/LMICs) have coexisting injuries requiring soft-tissue coverage (flaps). Yet, there is a lack of subspecialty care and flap training in Latin America. This study assesses the effectiveness of a surgical skills training course in improving rotational and free flap knowledge and identifies barriers these types of flaps.

Materials and Methods: Participants attending a surgical skills training course in Guadalajara, Mexico completed a pre/post-course flaps knowledge survey consisting of 15 questions from the plastic surgery in-training examination and also completed a 7-point Likert survey regarding perceived barriers to performing flaps at their institution.

Results: Of the course participants, 17 (44.7%) completed the pre-course knowledge survey, 24 (63.2%) completed the post-course survey, and 37 (97.4%) completed the barriers survey. Scores improved from pre- to post-course knowledge surveys (39.6% to 53.6%, p=.005). Plastic surgery subsection scores also improved (39.0% to 60.4%, p=.003). Twenty-five percent of attendees received prior flap training and had plastic surgeons available to perform flaps. Few participants (38.9%) reported flap procedures being commonly completed at their hospitals. Participants stating that flaps were uncommon in their hospital reported more institutional barriers and less access to dermatomes. These participants also reported lack of operating room and surgical personnel availability.

Conclusion: A surgical skills training course may be useful in improving knowledge of soft-tissue coverage procedures. There are also modifiable physician and institutional barriers that can improve the ability to perform rotational and free flaps as identified by the course participants.

Introduction

Musculoskeletal injuries are a major cause of global morbidity and mortality, with rates of extremity injuries in low- and low-middle-income countries (LMICs) exceeding those of high-income countries (HICs) 2 to 5-fold.[1,2] Lower extremity fractures are among the top nonfatal injuries sustained globally, and a significant amount of these injuries in LMICs present with soft-tissue injuries requiring muscle flaps or skin grafts.[3,4] Further adding to the burden of disease, despite the status of many Latin American countries as middle- to upper-middle income countries, there is still an unequal distribution of wealth in these countries, predisposing a significant proportion of their populations to medical conditions normally found in countries with lower GDPs.[5] Failure to properly manage soft-tissue injuries leads to an increased risk of infection and amputation, while implementation of appropriate soft-tissue management allows for adequate wound closure and reduced rates of nonunion.[6]

Multidisciplinary treatment is often required for successful management of fractures with accompanying soft-tissue defects, but LMICs face limited access to specialty care.[1,7] For this reason, there exists a strong need for more training, particularly as it pertains to soft-tissue coverage techniques. Knowledge exchange and training courses conducted by HIC specialists who can teach local professionals is a suggested method to build surgical capacity.[8-10] Training local orthopaedic surgeons in locations where there is little surgical subspecialist care may be a solution to promote complex soft-tissue defect management in LMICs,[11-13] and the Surgical Management and Reconstructive Training (SMART) course is one such approach that teaches orthopaedic surgeons the principles of soft-tissue reconstruction and complex fracture management.[10] The curriculum emphasizes lower extremity soft-tissue coverage (flaps) that can be performed without microvascular surgery.[4,14] A follow-up study of a recent SMART course showed that course attendees report increased confidence in and competency of plastic surgery techniques when performing muscle flaps, as well as a 93% self-reported success rate of flap surgeries performed post-course.[4,15]

Despite SMART courses delivering potentially promising outcomes, many participants from LMICs have difficulty applying the course concepts in actual practice. Local resource constraints and pedagogical issues, among other barriers, may be responsible for attendees unsuccessfully implementing their newly acquired knowledge. A SMART course was recently completed in Mexico, a country in which the open tibia fracture annual incidence may be as high as 50,000 per year[16] for surgeons in Latin America. Based on prior studies, we hypothesized that the SMART course would aid in knowledge acquisition and retention in a cohort of Latin American surgeons and that multiple barriers exist to performing flaps including resource limitations and lack of extensive surgical training. We thus completed a survey of SMART course participants in order to assess knowledge acquisition and to identify barriers to performing soft-tissue reconstruction.

Materials and Methods

The inaugural 2019 SMART course in Latin America was similar to prior courses in Nepal, Tanzania, and San Francisco and consisted of didactics, case-based discussions, and video review of cadaver dissections.[4,14,15,17] This study was supported by the Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT) and approved as exempt by the institutional review board of the University of California, San Francisco.

Soft-tissue coverage knowledge survey
A soft-tissue coverage knowledge survey was developed from retired United States plastic surgery in-training examination questions with the input of a fellowship trained plastic surgeon and two trauma fellowship trained orthopaedic surgeons. The survey consisted of 15 questions, with half of the questions pertaining to plastic surgery and lower extremity flap procedures, and the other half pertaining to orthopaedic surgery and management of lower extremity open fractures with soft-tissue defects. The survey was translated into Spanish and physical copies were provided to the participants for the pre- and post-course assessment.

Barriers to performing soft-tissue coverage procedures survey
Investigators developed a survey based on the existing literature[18-20] and the expert opinions of SMART course faculty and local FEMECOT partners. The survey utilized a 7-point Likert scale to assess participant familiarity with flaps, performance of these procedures in their hospital, confidence in performing flaps, and physician, institution, and patient barriers to carrying out flaps. The Likert scale was 7-points (1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Neutral, 5 = Slightly Agree, 6 = Agree, 7 = Strongly Agree). The survey was also translated into Spanish and completed by course participants during the four-day course. Participant subgroups were identified a priori to assess confidence and barriers to performing flap procedures. These groups included participants having received previous flap training, those stating that flaps were commonly performed in their hospital, and those stating that their prior training was adequate.

Statistical analysis
Descriptive statistics are reported to summarize participant knowledge survey and barriers survey responses. An unpaired, one-sided Student *t* test was used for assessment of average knowledge score between pre- and post-test groups. For the flap barriers survey, an unpaired, two-sided Student *t* test was used for assessment of continuous data and Pearson's Chi-Squared test for categorical data. All data analysis was completed using STATA SE v15.0 (STATACorp, College Station, TX) with significance set to $p<.05$.

Results
The SMART course consisted of 38 participants from three Latin American countries with the majority from Mexico (89.9%) and the others from Cuba (5.6%) and Venezuela (5.6%). No participant had previously attended a SMART course. The majority were male (94.6%), orthopaedic surgeons (91.2%), and fellowship trained in orthopaedics and musculoskeletal trauma (62.2%). Few participants (25%) stated that plastic surgeons are readily available to perform flaps in their hospital, and few (25%) had received any prior flap training. Flaps were reported as uncommonly performed in most hospitals (61.1%). While the majority of participants do not have dermatomes readily available (66.7%), the majority reported access to humby knives (88.2%). Participants most commonly cited physician (39.4%) or institutional issues (36.4%) as being the most important barriers (Table 1).

Knowledge survey results
Overall, participants performed significantly better on the post-course survey compared with the pre-course survey, with scores improving from 39.6% ± 15.9 to 53.6% ± 17.1 ($p=.005$). Participants also performed significantly better on the plastics component of the survey, with

pre-course and post-course scores improving from 39.0% ± 22.5 to 60.4% ± 24.4 (p=.003). Participants improved on the orthopaedics component of the survey from 40.3% ± 15.3% to 45.8% ± 22.2% (p=.1777) (Figure 1).

Barriers survey results

Nearly half of all participants did not agree that they successfully treat flap complications (48.2%), and the majority did not agree that they felt comfortable designing the correct flap for a patient in need of soft-tissue coverage (51.9%). Similarly, more than half of participants did not agree that they commonly use flaps for Gustilo-Anderson Type IIIB open tibia fractures (54.5%). Participants consistently found that institutional issues were significant barriers to performing flaps, with numerous participants either disagreeing or strongly disagreeing that their institution supports orthopaedic surgeons performing flap procedures (34.4%). Similarly, many either disagreed or strongly disagreed to feeling appropriately compensated for performing flaps (48.4%) and having enough operating room (OR) time (23.6%) and surgical personnel availability (29.4%). A number of participants also disagreed or strongly disagreed that their hospital had enough resources for post-operative flap care (23.6%) (Figure 2).

There were no significant differences found regarding participant attitudes toward any barriers between participants with prior flap training versus those without. Participants' confidence in designing a flap was significantly lower among participants stating that flaps were uncommonly completed at their hospital (3.8 vs. 5.3, p=.050). Availability of dermatomes was also reported to be lower in this group (12.5% vs. 57.1%, p=.010), and greater numbers of these participants reported that they lack peer support (3.3 vs. 6.0, p<.001), institutional support (3.2 vs. 4.9, p=.038), operating room availability (3.9 vs. 6.1, p=.002), and surgical personnel availability (3.3 vs. 5.7, p=.029). Lastly, this group reported lack of sufficient hospital resources for post-operative flap care (3.9 vs. 5.5, p=.029) (Table 2). Those with inadequate prior flap training reported feeling less confident in treating flap complications (4.1 vs. 6.0, p=.027), choosing the correct flap (4.2 vs. 6.2, p=.022), and correctly designing a flap (4.0 vs. 6.0, p=.0141). They also reported less common use of soft-tissue coverage/flaps for Gustilo-Anderson Classification type IIIB fractures (3.4 vs. 5.8, p=.010) (Table 2).

Discussion

In this study, we report the results of a survey of Latin American participants attending an orthopaedic and soft-tissue coverage procedure surgical training course in Mexico. Among attendees, there was improved immediate post-course knowledge of soft-tissue coverage procedures, particularly pertaining to plastic surgery. We identified several barriers to performing flaps including lack of plastic surgeon availability, inadequate training, lack of dermatome access, poor institutional and peer support, and constrained hospital resources for post-operative flap care.

Our findings are consistent with prior literature from lower resourced environments, demonstrating a lack of personnel with surgical technical expertise, requisite equipment, and institutional support in order to perform soft-tissue coverage procedures. A recent systematic review identified that key barriers to surgical care included lack of local resources, surgical expertise, and costs related to care.[7] More specific to plastic surgery, a study from Nepal similarly identified a lack of plastic surgery surgical equipment, surgical specialists, and

necessary structure and training for plastic surgeons.[8] A similar survey study from Vietnam found that respondents reported a lack of surgical supplies, sufficient training, and prohibitive treatment costs.[19] Finally, physicians in South Africa, an upper-middle income country, note that they, too, do not have enough plastic surgeons to meet the increasingly large amount of lower extremity trauma. The report from South Africa advocates for training orthopaedists in soft-tissue coverage procedures in settings where it may be challenging to rapidly scale the plastic surgery workforce.[11]

Orthopaedic training programs in LMICs have already been noted in the literature to be cost-effective measures for treating the large volume of musculoskeletal trauma. Grimes et al. found that an orthopaedic clinical officer training program in Malawi cost $92 per DALY averted, which is dramatically less costly than other common global health interventions such as anti-retroviral therapy for HIV or Malaria.[21-23] Similarly, in Haiti, a training program for orthopaedic fellows had a cost of only $133.97 per DALY averted.[24] It stands to reason that training orthopaedic surgeons in performing flap procedures in LMICs may be similarly cost-effective as other plastic surgery interventions. For example, across various LMICs, cleft lip and palate surgery costs from as little as $15 to $96 per DALY averted.[25,26]

The SMART course model is potentially efficacious in scaling up orthopaedic surgeon skills in performing flaps.[4,15] These courses may have an additional knock-on effect by which surgeons will gain the skills to not only perform flap procedures, but also to teach such procedures to their peers. As many of the participants felt they lacked peer and institutional support to perform flap procedures, the SMART course may be a potential way to address these barriers. Participants may be able to act as local champions for flap completion at their institution by utilizing their new skills and providing evidence that flaps are feasible in resource limited settings.[27-31]

This study has several limitations. The knowledge surveys are an unvalidated tool for evaluating flap knowledge, and they do not assess long-term knowledge acquisition and retention. A longer follow-up period to assess knowledge retention would be valuable for assessing long-term course efficacy. The knowledge surveys were also not individually identifiable to maintain participant confidentiality. This resulted in unequal participation in the pre- and post-course surveys, which affected the type statistical analysis employed. However, the results are consistent with prior SMART course data demonstrating efficacy in improving post-course knowledge survey scores.[15] This study has a small sample size, and its findings may not be generalizable. Course attendees may have been more likely to attend given their lack of flap training thus identifying barriers that may not be perceived by surgeons at large. Last, the barriers survey is an unvalidated instrument, and it may not capture all barriers to performing flaps among this cohort.

Nonetheless, this is the first study we are aware of to report on the barriers to performing soft tissue coverage procedures among Latin American surgeons. We identify that many surgeons receive inadequate flap training and that a surgical skills training course may be an effective way to improve knowledge of these procedures. Furthermore, we identify cost-effective ways to overcome local barriers including increasing dermatome access, improving institutional and peer support, and providing adequate resources for post-operative flap care. In addressing these barriers, Mexican orthopaedic and plastic surgeons may begin reducing the morbidity of patients with severe lower extremity traumatic injuries.

Figure 1. Average overall knowledge surveys scores with average score in plastics and orthopaedics subdomains before the SMART course and increase in post-course average score. *Statistically significant increase in average score, p<.05.

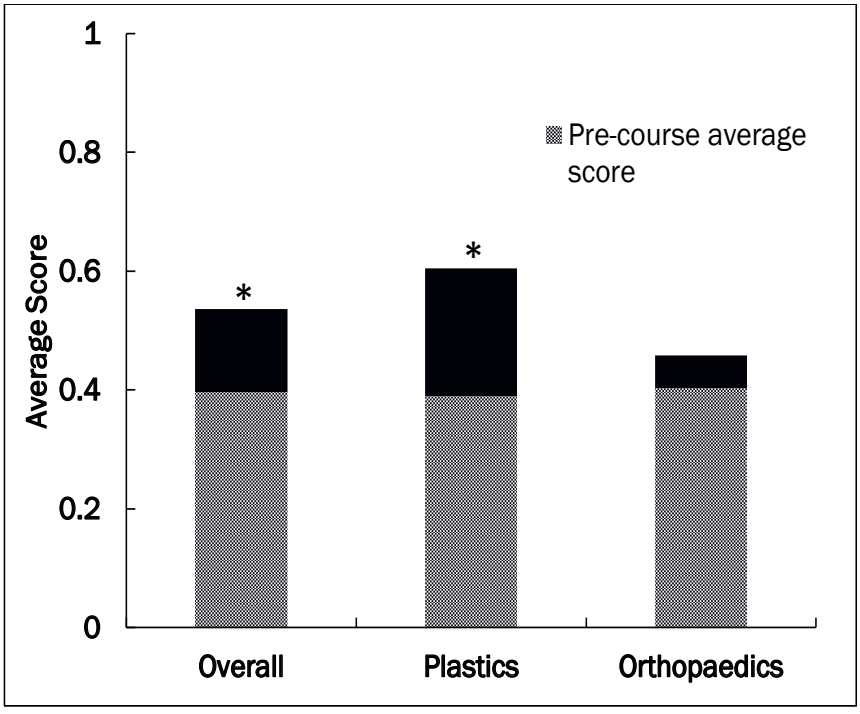


Figure 2. Participant response rate to Likert-scale barriers survey questions based on percentage of responses among overall course group.

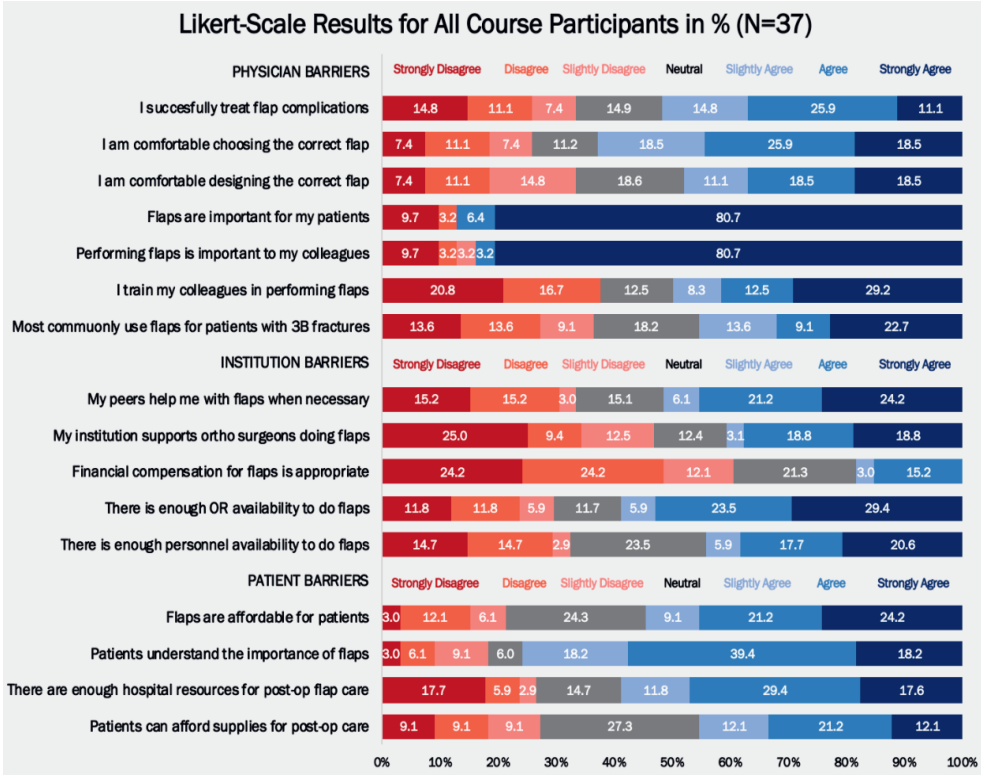


Table 1. Course participant characteristics

	N = 37 (%)*
Male	35 (94.6)
Surgeon type	
Orthopaedic	34 (91.2)
Plastic	2 (5.4)
General	1 (2.7)
Practice country	
Mexico	32 (88.9)
Cuba	2 (5.6)
Venezuela	2 (5.6)
Completed fellowship	
Musculoskeletal trauma	23 (62.2)
Hand surgery	5 (13.5)
Plastics	2 (5.4)
General trauma	7 (18.9)
Plastics surgeons readily available	9 (25.0)
Previous flap training	9 (25.0)
Prior training was adequate	7 (36.8)
Flaps commonly done	14 (38.9)
Regularly perform following flaps	
Split-thickness skin graft	16 (45.7)
Rotational muscle flap	11 (35.5)
Free flap	4 (14.3)
Dermatomes readily available	10 (33.3)
Humby knives readily available	30 (88.2)
Most common treatment for 3B fractures†	
Negative Pressure Wound Therapy	15 (45.5)
Refer to plastic surgery	8 (24.2)
Split-thickness skin graft	4 (12.1)
Refer to another center	2 (6.1)
Saline dressings	1 (3.0)
Most important barriers	
Physician	13 (39.4)
Institution	12 (36.4)
Patient	8 (24.4)

*Not all question had complete responses
†3B (Gustilo-Anderson Classification type 3B open tibia fractures)

Table 2. Sub-group analysis of barriers to soft-tissue coverage procedures

Flaps are commonly done in my hospital	**Yes (Mean)***	**SD**	**No (Mean)***	**SD**	**P Value**
I am comfortable designing the correct flap	5.3	2.1	3.8	1.6	0.050
My peers help me with flaps when necessary	6.0	1.6	3.3	1.9	<0.001
My institution supports ortho surgeons doing flaps	4.9	2.1	3.2	2.3	0.038
Financial compensation for flaps is appropriate	3.4	1.9	2.7	1.6	0.228
There is enough OR availability to do flaps	6.1	1.6	3.9	2.1	0.002
There is enough personnel availability to do flaps	5.7	1.8	3.3	1.8	<0.001
There are enough hospital resources for post-op flap care	5.5	1.7	3.9	2.2	0.029
Previous flap training was adequate	**Yes (Mean)***	**SD**	**No (Mean)***	**SD**	**P Value**
I successfully treat flap complications	6.0	1.1	4.1	1.7	0.027
I am comfortable choosing the correct flap	6.2	1.2	4.2	1.6	0.022
I am comfortable designing the correct flap	6.0	1.3	4.0	1.6	0.014
I most commonly use flaps for 3B patients	5.8	1.3	3.4	1.7	0.010

*Weighted mean using a 7-pt Likert-scale; 1=strongly disagree, 2=disagree, 3=slightly disagree, 4=neutral, 5=slightly agree, 6=agree, 7=strongly agree

References

1. Mock C, Cherian MN. The global burden of musculoskeletal injuries: challenges and solutions. *Clin Orthop Relat Res*. 2008;466(10):2306-2316.
2. Gosselin RA, Spiegel DA, Coughlin R. Injuries: the neglected burden in developing countries. *Bull World Health Organ*. 2009;87:246-246a.
3. Chalya PL, Dass RM, Mchembe MD, et al. Citywide trauma experience in Mwanza, Tanzania: a need for urgent intervention. *J Trauma Manag Outcomes*. 2013;7:9.
4. Wu HH, Patel KR, Caldwell AM, et al. Surgical Management and Reconstruction Training (SMART) Course for international orthopedic surgeons. *Ann Glob Heal*. 2016;82:652-8.
5. Aguila E, Akhmedjonov A, Basurto-Davila R, et al. United States and Mexico: ties that bind, issues that divide. Santa Monica, CA; 2012. Available at: https://www.rand.org/pubs/monographs/MG985-1.html. Accessed July 28, 2019.
6. Pollak AN, McCarthy ML, Burgess AR. Short-term wound complications after application of flaps for coverage of traumatic soft-tissue defects about the tibia. The Lower Extremity Assessment Project (LEAP) Study Group. *J Bone Jt Surg Am*. 2000;82:1681-91.
7. Grimes CE, Bowman KG, Dodgion CM, et al. Systematic review of barriers to surgical care in low-income and middle-income countries. *World J Surg*. 2011;35:941-50.
8. Mishra B, Koirala R, Tripathi N, et al. Plastic Surgery—myths and realities in developing countries: experience from Eastern Nepal. *Plast Surg Int*. 2011:870902.
9. Nguyen TA. Soft tissue coverage at the resource-challenged facility. *Clin Orthop Relat Res*. 2008;466:2451-6.
10. Conway DJ, Coughlin R, Caldwell A, et al. The Institute for Global Orthopedics and Traumatology: a model for academic collaboration in orthopedic surgery. *Front Public Heal*. 2017;5:146.
11. Ngcelwane M. Expanding the orthopaedic training programme to improve the management of lower extremity trauma. *SA Orthop J* . 2015;14:14-15.
12. Barbier O, Ollat D, Pasquier P, et al. Could the orthopaedic surgeon deployed in austere setting perform flaps on the leg? *Acta Orthop Belg*. 2017;83:35-9.
13. Boopalan PR, Nithyananth M, Titus VT, et al. Experience of using local flaps to cover open lower limb injuries at an Indian trauma center. *J Emerg Trauma Shock*. 2011;4:325-9.
14. Carey JN, Caldwell AM, Coughlin RR, et al. Building orthopaedic trauma capacity: IGOT international SMART course. *J Orthop Trauma*. 2015;29:S17-9.
15. Challa S, Conway D, Wu HH, et al. Can a 2-day course teach orthopaedic surgeons rotational flap procedures? An evaluation of data from the Nepal SMART course over 2 years. *J Orthop Trauma*. 2018;32:S38-42.
15. Va O-F, -Rodríguez M, S F-F. Incidencia de infección en fracturas expuestas ajustada al grado de exposición. *Acta Ortopédica Mex*. 2013.
16. Orihuela-Fuchs VA, Fuentes-Figueroa S. [Infection rate in open fractures adjusted for the degree of exposure]. *Acta Ortop Mex*. 2013;27:293-8.
17. Wu HH, Ibrahim J, Conway D, et al. Clinical research course for international orthopaedic surgeons: 2-year outcomes. *J Orthop Trauma*. 2018;32 Suppl 7:S35-7.
18. Stewart BT, Gyedu A, Abantanga F, et al. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg*. 2015;39:2613-21.
19. Yao CA, Swanson J, Chanson D, et al. Barriers to reconstructive surgery in low- and middle-income countries. *Plast Reconstr Surg*. 2016;138:887e-95e.

20. Ologunde R, Maruthappu M, Shanmugarajah K, et al. Surgical care in low and middle-income countries: burden and barriers. *Int J Surg*. 2014;12:858-63.
21. Grimes CE, Henry JA, Maraka J, et al. Cost-effectiveness of surgery in low- and middle-income countries: a systematic review. *World J Surg*. 2014;38:252-63.
22. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015;386:569-624.
23. Chao TE, Sharma K, Mandigo M, et al. Cost-effectiveness of surgery and its policy implications for global health: A systematic review and analysis. *Lancet Glob Heal*. 2014;2:334-345.
24. Carlson LC, Slobogean GP, Pollak AN. Orthopaedic trauma care in Haiti: a cost-effectiveness analysis of an innovative surgical residency program. *Value Heal*. 2012;15:887-93.
25. Corlew DS. Estimation of impact of surgical disease through economic modeling of cleft lip and palate care. *World J Surg*. 2010;34:391-6.
26. Magee WP, Vander Burg R, Hatcher KW. Cleft lip and palate as a cost-effective health care treatment in the developing world. *World J Surg*. 2010;34:420-7.
27. Bach O, Hope MJ, Chaheka CV, et al. Disability can be avoided after open fractures in Africa: results from Malawi. *Injury*. 2004;35:846-51.
28. Philip U, Mobash M, Osemogie W. Early management of open tibial fractures in Benin city - result of a structured treatment protocol. *J Med Biomed Res*. 2006;5:33-39.
29. Merrell JC, Tien NV, Son NT, et al. Introduction of microsurgery in Vietnam by a charitable organization: a 15-year experience. *Plast Reconstr Surg*. 2007;119:1267-73.
30. Tajsic NB, Husum H. Reconstructive surgery including free flap transfers can be performed in low-resource settings: experiences from a wartime scenario. *J Trauma*. 2008;65:1463-7.
30. Mathieu L, Mottier F, Bertani A, et al. Management of neglected open extremity fractures in low-resource settings: experience of the french army medical service in Chad. *Orthop Traumatol Surg Res*. 2014;100:815-20.

Acknowledgments
The authors thank the members of the board of FEMECOT for supporting the inaugural SMART course in Guadalajara, Mexico.

CHAPTER 12

12

Open Tibial Shaft Fracture Management in Argentina: An Evaluation of Treatment Standards in Diverse Resource Settings

MacKechnie MC[1], Albright PD2, Garabano G[3], Bidolegui F[4], Pereira S[4], Pesciallo CA[3], Miclau T[1], Argentina Study Group[†]

[1]Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA
[2]Department of Orthopaedic Surgery, University of Minnesota Medical School, Minneapolis, Minnesota, 55455, USA
[3]Hospital Británico, Perdriel 74, C1280, Buenos Aires, Argentina
[4]Hospital Sirio Libanes, Campana 4658, C1419, Buenos Aires, Argentina

OTA Int. 2022;5(3):e209-16

Abstract

Background: Argentina is a country with varying access to orthopaedic surgical care. The Argentine Association of Trauma and Orthopaedics (AATO) "Interior Committee" was developed to address potential regional differences and promote standardization of orthopaedic trauma care. The paper assesses the level of national standardization of the management of open tibia fractures across 9 provinces in Argentina.

Materials and Methods: Utilizing a matched-comparison group design, management of these injuries were assessed and compared between 3 groups: an "AATO Exterior Committee" consisting of surgeons that practice in Buenos Aires, and two "Interior Committees", comprising surgeons that practice in outlying provinces, 1 of which is affiliated with the AATO, and 1 that is not affiliated with the AATO. The study was conducted in 2 phases: phase 1 assessed open tibia fracture management characteristics, and phase 2 evaluated the management of soft-tissue wound coverage following open fractures.

Results: Soft-tissue coverage procedures for Gustilo Anderson Type IIIB fractures were more commonly performed by orthopaedic surgeons in Interior Committees than the AATO Exterior Committee. Greater rates of definitive wound coverage within 7 days post-injury were reported in both Interior Committees compared to the Exterior Committee. Plastic surgeons were reported as more available to those in the AATO Exterior Committee group than in the AATO Interior Committees.

Conclusion: While treatment patterns were evident among groups, differences were identified in the management and timing of soft-tissue coverage in GA Type IIIB fractures between Exterior Committee and both Interior Committees. Future targeted educational and surgical hands-on training opportunities that emphasize challenges faced in resource-limited settings may improve the management of open tibia fractures in Argentina.

Introduction

Globally, trauma represents the leading cause of morbidity and mortality in patients younger than 40 years of age,[1] with musculoskeletal injuries, such as open fractures, most commonly contributing to significant disability.[2,3] Open tibia fractures are common injuries that require specialized surgical care and soft-tissue wound coverage treatment.[4–7] In particular, these injuries bear a disproportionate burden of musculoskeletal disease in low-and middle-income countries (LMICs), predominantly in Latin America, due to high rates of road traffic injuries.[8,9]

Argentina, similar to other Latin American countries, has varying access to orthopaedic surgical care between its provinces; the Level I trauma hospitals are mostly concentrated in larger urban centers and its capital, Buenos Aires. In contrast, more resource-limited lower-level trauma centers are in the peripheral provinces with smaller, rural cities. Unequal access to care may occur, in large part, due to disparities in resource allocation between provinces.[10–12] In an effort to address potential regional differences, the Argentine Association of Trauma and Orthopaedics (AATO), developed an "Interior Committee," comprising orthopaedic surgeons that practice in outlying provinces across Argentina. The Interior Committee sought to promote national standardization of orthopaedic trauma care to achieve best practices.

This paper assesses the management of open tibia fractures across provinces in Argentina and provides insight into the level of standardized treatment of a challenging musculoskeletal injury. The findings may be used to address disparities in care through educational opportunities and further outreach efforts.

Materials and Methods

Argentinian orthopaedic surgeons who treat open tibia fractures were invited to participate in the study. These surgeons consisted of 3 groups. The first group, an "AATO Exterior Committee," included 19 orthopaedic surgeons that practiced in Buenos Aires and who were active members of the AATO. The second group included an "AATO Interior Committee" of 20 orthopaedic surgeons that practiced in provinces outside of Buenos Aires and who were active members of the AATO. The third group included a "Non-AATO Interior Committee" of 20 orthopaedic surgeons that practiced in provinces outside of Buenos Aires and who were not affiliated with the AATO. A matched-comparison group design was utilized in this study to reduce confounding variables.[13] Participants in all 3 groups were selected based on their similar baseline characteristics including age, gender, and years in practice to better determine treatment patterns and differences across cohorts in Argentina (Table 1). This study was conducted in 2 phases.

Phase 1: Open tibia fracture management

An initial survey was distributed to orthopaedic surgeons to assess the management of open tibia Gustilo Anderson Classification (GA) Type I/II and Type III fractures.[14] The 65-question self-reported survey was designed in Spanish and evaluated the timing and treatment strategies for antibiotic prophylaxis, irrigation and debridement, fracture stabilization, and wound management. Demographic information including years in practice, specialty training, and treatment preferences was also collected. Survey questions were designed based on a review of the literature and further evaluated by 3 independent, trauma fellowship-trained orthopaedic surgeons. The survey was deemed exempt by the Institutional Review Board at the University of California, San Francisco.

Phase 2: Management of soft-tissue wound coverage
Based on the responses from the phase 1 survey, a second survey was distributed to the same orthopaedic surgeon-participants. This 36-question self-reported survey was designed by 2 independent microvascular fellowship-trained orthopaedic and plastic surgeons. The survey evaluated their management of wound coverage following open fractures and queried the availability of wound care and operating room resources. The survey was deemed exempt by the local Institutional Review Board.

Statistical Method
The data were analyzed using Fisher exact tests with P=.05 as the significance level to assess for significant differences in treatment techniques between the 3 cohorts. Analysis was conducted using STATA SE Version 17 (StataCorp).

Results
Demographic information
The phase 1 and phase 2 surveys were completed by 59 orthopaedic surgeons, representing 9 provinces across Argentina: Buenos Aires, Chaco, Córdoba, Chubut, Neuquén, La Rioja, Santa Cruz, Santa Fe, and Tucumán (Figure 1). Overall, 95% of the participants were male with a mean age of 40.5 years and 45% of participants held a resident-teaching position. All participants (100%) completed residency training of which 42 (72%) were fellowship-trained. When stratified by groups, the AATO Exterior Committee group had a higher percentage of fellowship-trained colleagues than the Non-AATO Interior Committee group (95% vs. 45%, P=.001). This significant difference in training was also observed between the AATO Interior Committee group and the Non-AATO Interior Committee group (78% vs. 45%, P=.048). Practice experience ranged among participants, with the most commonly reported timeframe being 6 to 10 years (32%). Less than half (41%) of the participants had received soft-tissue coverage training in some capacity, either through formal training or mentorship from a colleague. The majority of survey participants (88%) most commonly treated between 0 and 10 open tibia fractures annually (Table 2).

Phase 1: open tibia fracture management
In phase 1, all 3 groups demonstrated consistent treatment protocols for GA Type I/II fractures regarding irrigation and debridement, fracture stabilization, wound closure, and antibiotic prophylaxis (Table 3). Most of the AATO Exterior Committee (95%), AATO Interior Committee (100%), and Non-AATO Interior Committee (100%) groups performed operative irrigation and debridement within 24 hours of injury. Further, the AATO Exterior Committee, AATO Interior Committee, and Non-AATO Interior Committee most commonly utilized delayed internal fixation for fracture stabilization (84% vs. 85% vs. 90%) and opted for primary wound closure (95% vs. 100% vs. 95%), respectively. In addition, most participants across all groups administered antibiotics within 3 hours of hospital presentation (74% vs. 70% vs. 65%).

A statistically significant difference was identified, however, in the performance of soft-tissue coverage procedures by orthopaedic surgeons for GA Type IIIB fractures between the AATO Exterior Committee and the AATO Interior Committee (0% vs. 35%, P=.004) groups. This

discrepancy was also observed between the AATO Exterior Committee group and the Non-AATO Interior Committee group (0% vs. 50%, P<.001).

Phase 2: management of soft-tissue wound coverage
All groups commonly reported patient arrival to the operating room within a 6-hour timeframe. Regarding soft-tissue coverage timing between the AATO Exterior Committee and the AATO Interior Committee, the latter group reported greater rates of definitive wound coverage within 7 days (32% vs. 74%, P=.009). This difference was also identified between the AATO Exterior Committee group and the Non-AATO Interior Committee group (32% vs. 75%, P=.007).

Moreover, the AATO Exterior Committee group more commonly reported plastic surgeons as the primary providers for soft-tissue coverage flaps in comparison to the Non-AATO Interior Committee group (74% vs. 40%, P=.043). In addition, plastic surgeons were reported as more available to those in the AATO Exterior Committee group than in the AATO Interior Committee group (84% vs. 35%, P=.005). This was also evident between the AATO Exterior Committee group and the Non-AATO Interior Committee group (84% vs. 30%, P=.003) (Table 4). No significant differences existed in the number of orthopaedic surgeons who received soft-tissue training among the AATO Exterior Committee (42%), the AATO Interior Committee (45%), and the non-AATO Interior Committee (35%) groups.

Regarding wound care and operating room resources, a needs analysis showed that most institutions have access to Negative Pressure Wound Therapy (85%). Other instruments, such as wall suction outside the operating room (42%), Humby blades, and other manual blades for harvesting skin graft (37%) were less common. Microsurgery instruments (15%), skin graft meshers (13%), and handheld dopplers (12%) were the least accessible resources. Further, occlusive dressings were most commonly available in the operating room (85%), with less than half of the participants (45%) citing access to saline-moistened sterile gauze dressings and anti-microbial dressings (28%), including antibiotic ointments and betadine/iodine-based dressings (Table 5). Finally, for lower extremity wounds with exposed bone that cannot primarily be closed, participants in all 3 groups reported performing muscle flaps most commonly for proximal third and middle third defects. Regarding a lower extremity distal third defect, participants in the Exterior Committee and the AATO Interior Committee most commonly performed fasciocutaneous flaps, and the Non-AATO Interior Committee most frequently used direct wound care (Figure 2).

Discussion
This study evaluated the management of open tibia fractures between surgeons affiliated and non-affiliated with the national orthopaedic and traumatology society (AATO) throughout nine Argentinian provinces. The Interior Committee was developed by the AATO to promote national standardization of orthopaedic trauma care across Argentina. Common reasons for nonstandard management of these musculoskeletal injuries in LMICs include limited resources, level of surgeon expertise, knowledge deficits, and lack of specialized training.[15–18] Educational courses are offered at the annual AATO conference on a variety of topics in orthopaedic trauma, including the management of open tibia fractures, and the type and timing of soft-tissue coverage. Soft-tissue wound coverage surgical techniques, however, have not been specifically targeted.

Though the Non-AATO Interior Committee had potential for inconsistent reporting given its greater geographic separation and non-affiliated status with the AATO, as well as lower rates of fellowship-trained colleagues, there were more similarities than differences in the management of open tibia fractures reported across all study groups. Many of the results in this study are consistent with treatment patterns previously identified across Latin America, particularly pertaining to timing of antibiotic administration, irrigation and operative debridement, and utilization of delayed internal fixation and primary closure.[19,20] In these aspects, the Argentinian orthopaedic surgeon groups demonstrate standardization in the management of open tibia fractures. Yet, differences in the management of soft-tissue defects in GA Type IIIB fractures were evident between the orthopaedic surgeons based in the urban group (AATO Exterior Committee), and those in more remote settings (AATO and Non-AATO affiliated Interior Committees).

Notably, the AATO Exterior Committee reported performing soft-tissue coverage less frequently within a 7 day post-injury standard than the Interior Committee surgeons.[21–24] The AATO Exterior Committee also reported having more access to plastic surgeons at their institutions, in contrast to the AATO and Non-AATO Interior Committee groups that cited a lack of available plastic surgeons to provide definitive coverage. This discrepancy in access to multidisciplinary management is well-documented in LMICs worldwide.[15,16,18,25–27] This might also be observed in resource-rich countries, and merits further evaluation. The reported increased delay to definitive coverage by the AATO Exterior Committee surgeons seems counter-intuitive, as greater access to specialist coverage should likely lead to fewer delays to definitive soft-tissue coverage. One possible explanation for these findings is that despite access to plastic surgeons, reliance on their availability may result in greater delays relative to timelier coverage performed by orthopaedic surgeons. Further examination into the reasons for these differences in coverage treatment and timing is necessary.

With only 40% of participants having had training in soft-tissue reconstruction and the lack of specialized care in more rural provinces, there is a need for Argentinian orthopaedic surgeons with this specialized skill. In addition, of 17 wound care and operating room resources, Negative Pressure Wound Therapy was the only resource that was reported available to more than half of the participants (85%). Given most of the participants' limited resources and lack of soft-tissue specialists, particularly for Interior Committee groups, a phase 3 study to create a specific didactic and hands-on wound coverage technique course could improve open tibia fracture management and treatment standardization.[28] Previous studies in LMICs have reported on the efficacy of such courses, including improving patient outcomes and reducing long-term disability. These courses educate orthopaedic surgeons on the basic principles and techniques of open fracture management and lower extremity flap reconstruction procedures, with an emphasis on challenges faced in resource-limited settings.[16,29,30] Improvement in competency scores, skill acquisition, and comfort in performing rotational and free flaps have been documented as a result of these courses.

To our knowledge, this study is the first to evaluate the level of standardization of open tibia fracture management across Argentina's diverse resource settings. The Interior Committee is an effective method that can be used as a model by other national professional societies interested in

developing best practice protocols in resource-limited environments. The results of this study can help to advocate for better allocation of wound care resources, operative personnel, and hands-on training opportunities needed to improve care for patients with musculoskeletal injuries.

This study has several limitations. This 2-phase study was conducted through self-reported assessments, potentially allowing for participants to respond to the perceived optimal treatment standards, rather than those practiced. The sample size is small and represents 9 of 23 provinces across Argentina. Nevertheless, the 9 provinces represented in the study were socioeconomically diverse,[31] equally spread geographically across the country, and demonstrated fairly uniform treatment patterns. Study participants were also selected by the authors to match age, gender, and years in practice among groups, and thus, were subject to selection bias. However, matching variables a priori is a standard method for the match-comparison study design and allowed for a clearer examination of treatment preferences and differences across a diverse landscape.

Additionally, there may have been differences in the way the participants classified GA Type IIIB fractures, as this classification system was not specifically reviewed with the participants, and it has been shown to have only moderate agreement among surgeons.[32] Nevertheless, the GA classification is the most commonly used system in Argentina and GA Type IIIB injuries are a smaller subset of injuries that involve extensive soft-tissue damage.[14] Finally, this study focused on treatment patterns and not related patient outcomes. Treatment outcomes secondary to differences in practices is a subject that warrants future investigation.

In summary, the formation of an Interior Committee by the AATO sought to improve the quality of musculoskeletal care in Argentina. A difference in the use of soft-tissue coverage following GA Type IIIB fractures was identified between the orthopaedic surgeons in the Exterior Committee and Interior Committee groups, with the latter performing these procedures more often and in a timelier manner (<7 days). Further investigation behind the reason for this discrepancy in treatment is necessary. Future targeted surgical educational interventions that emphasize challenges faced in resource-limited settings may improve the management of open tibia fractures, representing a potential area for examination.

References

1. Simmons JW, Powell MF. Acute Traumatic Coagulopathy: Pathophysiology and Resuscitation. *Br J Anaesth*. 2016;117(Suppl 3):31-43.
2. Sunshine JE, Humbert AT, Booth B, Bowman SM, Bulgar EM, Sharar SR. Frequency of Operative Anesthesia Care after Traumatic Injury. *Anesth Analg*. 2019;129:141-146.
3. Richards JE, Medvecz AJ, O'Hara NN, Guillamondegui OD, O'Toole RV, Obremskey WT, et al. Musculoskeletal Trauma in Critically Injured Patients: Factors Leading to Delayed Operative Fixation and Multiple Organ Failure. *Anesth Analg*. 2020;131(6):1781-1788.
4. Clelland SJ, Chauhan P, Mandari FN. The epidemiology and management of tibia and fibula fractures at Kilimanjaro Christian Medical Centre (KCMC) in Northern Tanzania. *Pan Afr Med J*. 2016;25. doi:10.11604/pamj.2016.25.51.10612
5. Allende C, Bitar I, Cocco CA, Remondino RG, Ortiz N, Allende B. Fracturas de Alta Energía del Extremo Distal de la Tibia. Principios de Tratamiento y Resultados. *Rev Asoc Arg Ortop Traumatol*. 67(2):74-82.
6. Schemitsch E, Bhandari M, Guyatt G, Sanders D, Swiontkowski M, Tornetta P, et al. Prognostic Factors for Predicting Outcomes After Intramedullary Nailing of the Tibia. *J Bone Jt Surg Am*. 2012;94(19):1786-1793.
7. Bhandari M, Guyatt GH, Tong D, Adili A, Shaughnessy SG. Reamed Versus Nonreamed Intramedullary Nailing of Lower Extremity Long Bone Fractures: A Systematic Overview and Meta-Analysis. *J Orthop Trauma*. 2000;14(1):2-9.
8. Mock C, Cherian MN. The Global Burden of Musculoskeletal Injuries: Challenges and Solutions. *Clin Orthop*. 2008;466(10):2306-2316. doi:10.1007/s11999-008-0416-z
9. The World Bank Data. Mortality caused by road traffic injury (per 100,000 people). https://data.worldbank.org/indicator/SH.STA.TRAF.P5?end=2016&start=2016&view=bar
10. Palacios A, Espinola N, Rojas-Roque N. Need and Inequality in the use of health care services in a fragmented and decentralized health system: Evidence for Argentina. *Int J Equity Health*. 2020;19(1):67.
11. Rubinstein A, Zerbino MC, Cejas C, López A. Making Universal Health Care Effective in Argentina: A Blueprint for Reform. *Health Syst Reform*. 2018;4(3):2013-2213.
12. Padilla Rojas LG, Lopez Cervantes RE, Perez Atanasio JM, Sanchez MM, Gomez Acevedo JM, Kodima KE. Latin America Trauma Systems - Mexico and Brazil. *OTA Int*. 2019;2(S1):e020.
13. Rose S and van der Laan M. Why Match? Investigating Match Case-Control Study Designs with Causal Effect Estimation. *Int J Biostat*. 2009;5(1):1.
14. Kim PH, Leopold SS. Gustilo-Anderson Classification. *Clin Orthop Relat*. 2012;477(10):2388.
15. Gosselin RA, Spiegel DA, Coughlin RR, Zirkle LG. Injuries: The Neglected Burden in Developing Countries. *Bull World Health Organ*. 2009;87(4):246-247. doi:10.2471/blt.08.052290
16. Albright PD, Mackechnie MC, Jackson JH, et al. Knowledge deficits and barriers to performing soft-tissue coverage procedures: An analysis of participants in an orthopaedic surgical skills training course in Mexico. *OTA Int*. 2019;2(4):e044. doi:10.1097/OI9.0000000000000044
17. Holler JT, MacKechnie MC, Albright PD, Morshed S, Shearer DW, Terry MJ. The impact of inadequate soft-tissue coverage following severe open tibia fractures in Tanzania. *Plast Reconstr Surg*. 8(12):e3272.

18. Grimes CE, Bowman KG, Dodgion CM, Lavy CB. Systematic Review of Barriers to Surgical Care in Low-Income and Middle-Income Countries. *World J Surg*. 2011;35:941-950.
19. Albright PD, MacKechnie MC, Roberts HJ, Shearer DW, Padilla Rojas LG, Quintero JE, et al. Open Tibial Shaft Fractures: Treatment Patterns in Latin America. *J Bone Jt Surg*. 2020;00(e1):1-10. doi:http://dx.doi.org/10.2106/JBJS.20.00292
20. Bhandari M, Guyatt GH, Swiontkowski MF, et al. Surgeons' preferences for the operative treatment of fractures of the tibial shaft. An international survey. *J Bone Joint Surg Am*. 2001;83(11):1746-1752. doi:10.2106/00004623-200111000-00020
21. Cierny G III, Byrd HS, Jones RE. Primary versus Delayed Soft Tissue Coverage for Severe Open Tibial Fractures: A Comparison of Results. *Clin Orthop Relat Res*. 1983;(178):54-63.
22. D'Alleyrand JC, Manson TT, Dancy L, et al. Is Time to Flap Coverage of Open Tibial Fractures an Independent Predictor of Flap-Related Complications? *J Orthop Trauma*. 2014;28(5):288-293.
23. Hwang KT, Kim SW, Sung IH, Kim JT, Kim YH. Is Delayed Reconstruction Using the Latissimus Dorsi Free Flap a Worthy Option in the Management of Open IIIB Tibial Fractures? *Microsurgery*. 2016;26(6):453-459.
24. Clegg DJ, Rosenbaum PF, Harley BJ. The Effects of Timing of Soft Tissue Coverage on Outcomes After Reconstruction of Type IIIB Open Tibia Fractures. *Orthopaedics*. 2019;42(5):260-266.
25. Carey JN, Caldwell AM, Coughlin RR, Hansen S. Building Orthopaedic Trauma Capacity: IGOT International SMART Course. *J Orthop Trauma*. 2015;29 Suppl 10:17-19.
26. Ikem IC, Oginni LM, Bamgboye EA. Open fractures of the lower limb in Nigeria. *Int Orthop*. 2001;25(6):386-388. doi:10.1007/s002640100277
27. Holler JT, Albright P, Challa S, Ali SH, Martins D, Keys k et al. Barriers to Performing Soft Tissue Reconstruction Procedures among Orthopedic Surgeons in Lowand Middle-income Countries: Results of a Surgical Skills Training Course. *Plast Reconstr Surg Glob Open*. 2019;7(e2420):1-6.
28. Agarwal-Harding KJ, Kapadia A, Banza LN, Chawinga M, Mkandawire N, Kwon JY. Improving Management of Adult Ankle Fractures in Malawi. *JBJS*. 2020;103A(4):326-334.
29. Challa S, Conway D, Wu Hao Hua, et al. Can a Two-Day Course Teach Orthopaedic Surgeons Rotational Flap Procedures? An Evaluation of Data From the Nepal SMART Course Over Two Years. *J Orthop Trauma*. 2018;32 Suppl(7):S38-S42.
30. Wu HH, Kushal PR, Caldwell AM, Coughlin RR, Hansen SL, Carey JN. Surgical Management and Reconstruction Training (SMART) Course for International Orthopedic Surgeons. *Ann Glob Health*. 2016;82(4):652-658.
31. International Bank for Reconstruction and Development, The World Bank Group. Argentina: Escaping Crises, Sustaining Growth, Sharing Prosperity. Published online 2018:1-160.
32. Horn BD, Rettig ME. Interobserver Reliability in the Gustilo and Anderson Classification of Open Fractures. *J Orthop Trauma*. 1993;7(4):357-360.

Figure 1. Map of survey participants by province in Argentina

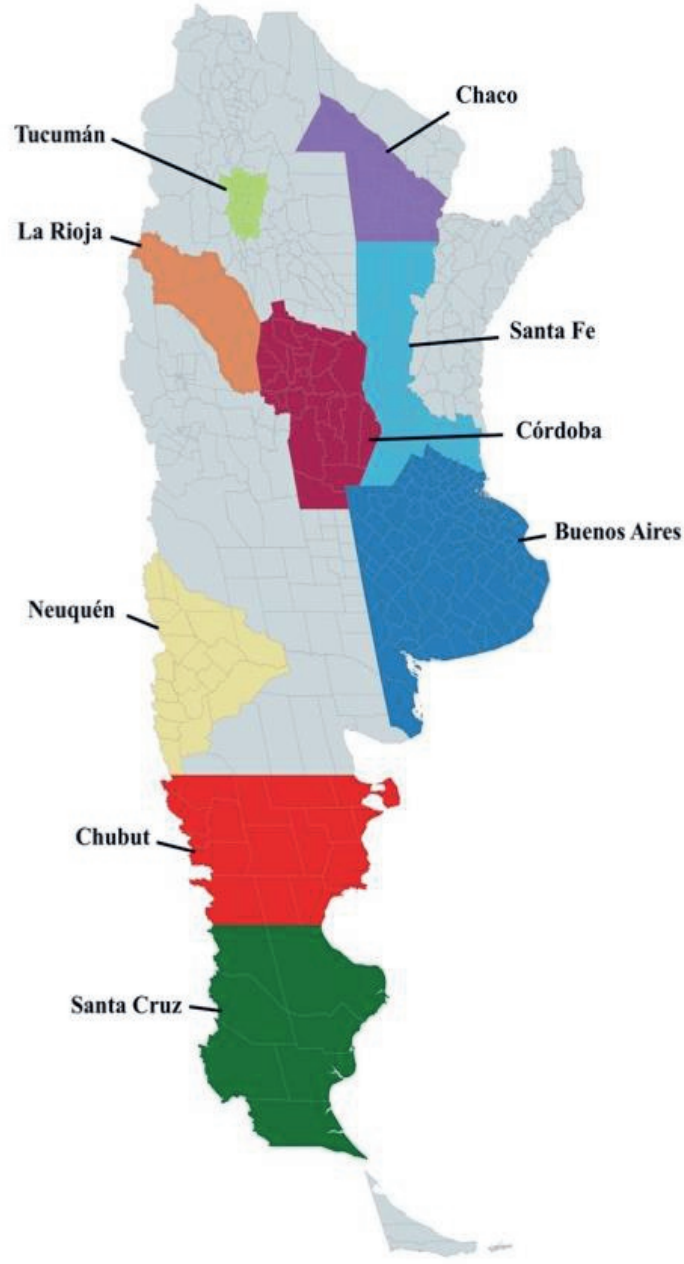


Figure 2. Orthopaedic surgeons' preferences for soft-tissue management of lower extremity proximal third, middle third, and distal third defects, stratified by groups

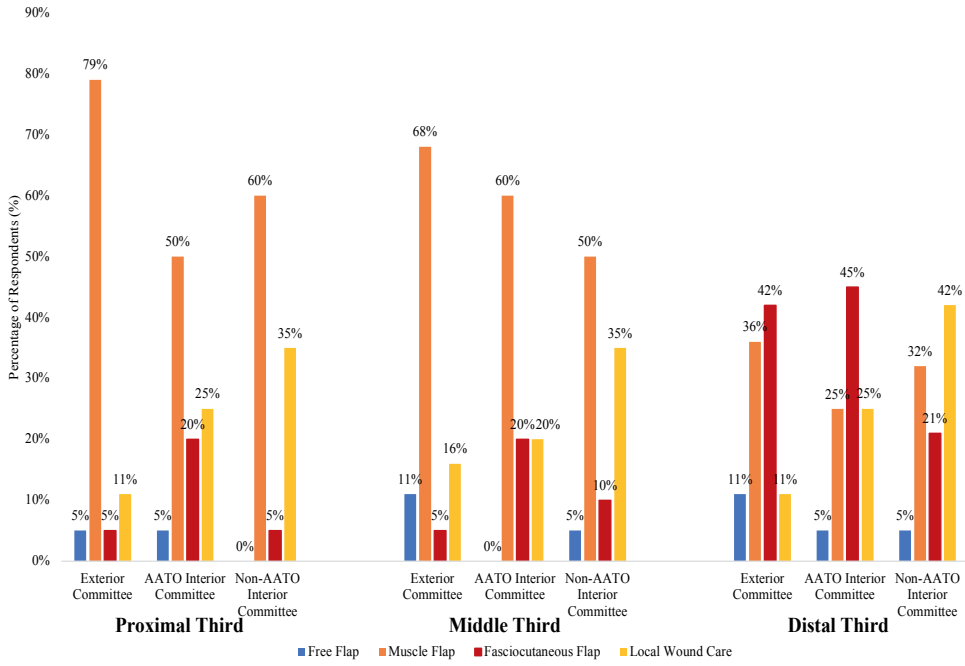


Table 1. Characteristics of matched cohorts

	AATO Exterior Committee (n=19)	**AATO Interior Committee (n=20)**	**Non-AATO Interior Committee (n=20)**
Total			
Mean age	40.1	40.3	41
Gender (male) (%)	94.7	95	95
Years in practice (mean)	10.6	10.3	10.4

Table 2. Demographic data of survey respondents

	Total N (%)
	59 (100)
Male	56 (95)
Years in practice	
0-5	14 (23.7)
6-10	19 (32.2)
11-15	17 (28.8)
16-20	7 (11.9)
>21	2 (3.4)
Residency training	59 (100)
Fellowship in ortho trauma or plastic surgery	42 (72.4)
Practice setting	
Combination	25 (42.4)
Private practice	24 (40.7)
Public practice	7 (11.9)
Academic practice	3 (5)
Supervise Residents	27 (45.8)
Received soft-tissue training?	24 (40.7)
Number of open tibia fractures personally treated each year	
0-10	51 (87.9)
11-20	7 (12.1)

*Various data not reported by all respondents

Table 3. Comparison of orthopaedic surgeons' management of open tibia fractures

	AATO Exterior Committee n (%)	**AATO Interior Committee n (%)**	**P Value**	**AATO Exterior Committee n (%)**	**Non-AATO Interior Committee n (%)**	**P Value**	**AATO Interior Committee n (%)**	**Non-AATO Interior Committee n (%)**	**P Value**
Total	*19 (100)*	*20 (100)*		*19 (100)*	*20 (100)*		*20 (100)*	*20 (100)*	
Irrigation and Debridement Average time to operative debridement									
<24 hours	18 (94.7)	20 (100)	0.487	18 (94.7)	20 (100)	0.487	20 (100)	20 (100)	1
>24 hours	1 (5.3)	0		1 (5.3)	0		0	0	
Fracture Stabilization Utilize primary versus delayed internal fixation									
Primary	3 (15.8)	3 (15)	1	3 (15.8)	2 (10)		3 (15)	2 (10)	1
Delayed	16 (84.2)	17 (85)		16 (84.2)	18 (90)	0.661	17 (85)	18 (90)	
Wound Closure Utilize primary versus delayed closure									
Primary	18 (94.7)	20 (100)	0.487	18 (94.7)	19 (95)	1	20 (100)	19 (95)	1
Delayed	1 (5.3)	0		1 (5.3)	1 (5)		0	1 (5)	
Antibiotic Prophylaxis Average time to antibiotics									
<3 hours	14 (73.7)	14 (70)	1	14 (73.7)	13 (65)	0.731	14 (70)	13 (65)	0.736
>3 hours	5 (26.32)	6 (30)		5 (26.3)	7 (35)		6 (30)	7 (35)	
Soft-Tissue Coverage Perform soft-tissue procedures for IIIB fractures									
Yes	0	7 (35)	**0.004**	0	10 (50)	**> 0.001**	7 (35)	10 (50)	0.337
No	19 (100)	13 (65)		19 (100)	10 (50)		13 (65)	10 (50)	

*Tests of significance completed with Fisher's exact test ($\alpha = 0.05$)

Table 4. Comparison of orthopaedic surgeons' management of soft-tissue coverage following open tibia fractures

	AATO Exterior Committee n (%)	**AATO Interior Committee n (%)**	**P Value**	**AATO Exterior Committee n (%)**	**Non-AATO Interior Committee n (%)**	**P Value**	**AATO Interior Committee n (%)**	**Non-AATO Interior Committee n (%)**	**P Value**
Total	*19 (100)*	*20 (100)*		*19 (100)*	*20 (100)*		*20 (100)*	*20 (100)*	
Average time to provide soft-tissue coverage									
<7 days	6 (31.6)	14 (73.7)	**0.009**	6 (31.6)	15 (75)	**0.007**	14 (73.7)	15 (75)	0.925
>7 days	13 (68.4)	5 (26.3)		13 (68.4)	5 (25)		5 (26.3)	5 (25)	
Average time for arrival to OR									
<6 hours	13 (68.4)	13 (65)	0.614	13 (68.4)	16 (80)	0.408	13 (65)	16 (80)	0.425
6-24 hours	6 (31.6)	6 (30)		6 (31.6)	4 (20)		6 (30)	4 (20)	
24-48 hours	0	1 (5)		0	0		1 (5)	0	
Who primarily provides soft-tissue coverage to GA-IIIB fractures?									
Plastic surgeon	14 (73.7)	11 (55)	0.263	14 (73.7)	8 (40)	**0.043**	11 (55)	8 (40)	0.547
Orthopaedic surgeon	5 (26.3)	7 (35)		5 (26.3)	8 (40)		7 (35)	8 (40)	
No available surgeon	0	2 (10)		0	4 (20)		2 (10)	4 (20)	
Do you have a plastic surgeon available at your institution?									
Yes	16 (84.2)	7 (35)	**0.005**	16 (84.2)	6 (30)	**0.003**	7 (35)	6 (30)	0.765
No	1 (5.3)	9 (45)		1 (5.3)	8 (40)		9 (45)	8 (40)	
Sometimes	2 (10.5)	4 (20)		2 (10.5)	6 (30)		4 (20)	6 (30)	
Have you had soft-tissue coverage training?									
Yes	8 (42.1)	9 (45)	0.855	8 (42.1)	7 (35)	0.648	9 (45)	7 (35)	0.519
No	11 (57.9)	11 (55)		11 (57.9)	13 (65)		11 (55)	13 (65)	

*Tests of significance completed with Fisher's exact test ($\alpha = 0.05$)

Table 5. Wound care and operating room resources

	Total n (%) *59 (100)*
Which OR resources do you have access to?[+]	
Negative Pressure Wound Therapy (NPWT or Wound VAC)	51 (85)
Wall suction outside the OR	25 (42)
Manual blade for harvesting skin grafts (e.g Humby blade)	22 (37)
Power dermatome	19 (32)
Magnifying loupes	15 (25)
Microsurgery instruments	12 (20)
Operating microscopes	9 (15)
Skin graft mesher	8 (13)
Handheld doppler	7 (12)
Which dressings do you have access to?[+]	
Occlusive dressing	51 (85)
Saline-moistened sterile gauze dressing	27 (45)
Anti-microbial dressing	17 (28)
What type of anti-microbial dressings do you have access to?[+]	
Antibiotic ointments	26 (43)
Betadine/Iodine-based dressing	26 (43)
Silvadene	11 (18)
Honey-based dressing	11 (18)
Dakins/Dilute bleach	5 (8)
Other	9 (15)
What type of microsurgical instruments are available at your institution?[+]	
Not sure	
8-0 suture (nylon, proline)	20 (33)
9-0 suture	14 (23)
Micro needle-holder	13 (22)
Curved micro dissecting scissors	12 (20)
Straight micro scissors	12 (20)
10-0 suture	11 (18)
Micro-pickups	9 (15)
Micro vessel dilator	9 (15)

*Various data not reported by all respondents

[+]Participants were able to select multiple responses

Acknowledgements

[†]Argentina Study Group (Corporate Authors)

Emiliano Acuña Kunz, MD (Hospital Zonal de Caleta Olivia); Ricardo Rodrigo Arri, MD (Sanatorio Norte); Damian Arroquy, MD (Clínica María Auxiliadora Olavarria); Federico Arroquy, MD (Hospital Privado de Comunidad); Ignacio Arzac Ulla, MD (Privado); Nicolas Azcona, MD (Hospital Municipal de General Villegas, Buenos Aires); Juan Manuel Barrios, MD (Hospital Mariano Etchegaray, Gral La Madrid, Clínica María Auxiliadora Olavarria); Matias Beatti, MD (Hospital Churruca); Martin Botta, MD (Clínica María Auxiliadora); Mariano Codesido, MD (Hospital Universitario Austral, Hospital Universitario Fundación Favaloro); Julio Gonzalo Juan Dasso, MD (Hospital Manuel B. Cabrera); Carolina Dominguez, MD (Hospital Provincial de Neuquén, "Eduardo Castro Rendon"); Debora Gabe, MD (Hospital Santa Teresita); Gustavo Gasparini, MD (Hospital de General Villegas); Walter Gavinoser, MD (Hospital Dr. Noé Yarcho de Rivera); Luciano Gentile, MD (Sanatorio Moreno); Guillermo Gotter Campo, MD (Clínica Zabala); Gonzalo Perez Herrera, MD (Sanatorio Antartida); Horacio Hererra, MD (Hospital Aleman, Buenos Aires); S. Denise Hochbaum, MD (Servicio de Ortopedia y Traumatología, Hospital Junín de los Andes); German Joannas, MD (Instituto Depuytren); Marcelo Juarez, MD (Hospital Zonal Caleta Olivia, Centro Médico Santa Cruz); Jonatan A. Lobo, MD (Hospital Sirio Libanes); German Lugones, MD (Clínica Yunes); Ezequiel Lulkin, MD (Hospital Sirio Libanes); Juan Maino, MD (Hospital Militar Central); Diego Mana, MD (Hospital Asociación Médica Bahía Blanca, "Dr. Felipe Glasman"); Luciano Mañero, MD (Clínica María Auxiliadora, Olavarria; Martin Mangupli, MD (Servicio de Ortopedia y Traumatología, Sanatorio Allende, Córdoba); Jose Farías Matus, MD (Hospital Plottier, Neuquén); Fernando Misione, MD (Policlinico Neuquén); Jesus Rey Moggia, MD (Hospital San Martin de la Plata); Gonzalo Muñoz, MD (Policlínico Neuquen); Tomás Nasello, MD (Hospital Sirio Libanes, Buenos Aires); Juan Alberto Laube Nikolajuk, MD (Sanatorio Antártida); Agustín Paz, MD (Clínica San Pablo, Trelew); Sebastian Pereira, MD (Hospital Sirio Libanes, Departmento de Ortopedia y Traumatología); Roberto Pelaez, MD (Hospital San Martín, Buenos Aires); Camilo Perlasco, MD (Clínica Pueyrredon); Pablo Poloni, MD (Sanatorio MAPACI); Gaston Rabey, MD (Sanatorio Padre Río- Reconquista, Santa Fe); Nicolas Robador, MD (Hospital Enrique Vera Barros, Institute Médico Quirúrgico Mercado Luna); Joaquín Anibal Rodriguez, MD (Hospital Británico de Buenos Aires); Andres Roncoroni, MD (Hospital Garrahan); Sergio Andrés Sandrigo, MD (Sanatorio Padre Rio, Reconquista, Santa Fe); Lara Saez, MD (Hospital San Carlos Capitán Sarmiento, Buenos Aires); Dennys Felipe Sarmiento, MD (Hospital Municipal General Villegas); Sebastian Sasaki, MD (Centro Médico Integral Fitz Roy); Harold Simesen de Bielke, MD (Sanatorio Model S.A., San Miguel de Tucumán, Tucumán); Juan Sebastián Soler, MD (Privado); Fernando Agustín Sommer, MD (Hospital Posadas, Misiones); Santiago Svarzchtein, MD (Centro Médico Integral Fitz Roy, Buenos Aires); Federico Tedeschi, MD (Ortopedia y Traumatología, Hospital San Martín de los Andes, Neuquén); Mauricio Vagnoni, MD (Hospital de Daireaux); Joaquin Valero, MD (Hospital de la Asociación Médica); Adrian David Villaroel Schvemer, MD (Servicio de Ortopedia y Traumatología, Hospital Regional de Comodora Rivadavia, "Dr. Víctor M. Sanguinetti", Chubut); Pablo Villegas, MD (Hospital Natalio Burd)

CHAPTER 13

General Discussion and Future Directions

General Discussion

Clinical Research: Regional Barriers

In order to address issues critical to Latin America, it is essential that clinical providers engage in investigative work on issues relevant to their populations. Results from these studies, in turn, should be disseminated through academic publications and across academic societies.[1] Despite Latin America's overwhelming volume of musculoskeletal injuries, peer-reviewed articles originating from Latin American countries are underrepresented in major orthopedic surgery journals,[2–4] fundamentally limiting the development of knowledge that could improve traumatic injury care and inform research and policy priorities. In an effort to overcome this gap, in 2011 the Osteosynthesis and Trauma Care Foundation sponsored a "Forum of the Americas", a meeting held to discuss ways to increase research capacity in the field of orthopaedic trauma surgery across Spanish-speaking Latin American countries.[5] **(Chapter 2)** In this meeting, experts from across Latin America identified barriers to research and reasons for lack of robust research infrastructure. While research was considered a requirement for professional advancement in many surgeons' positions, the lack of structural and financial support, as well as the lack of investigative background precluded their participation in clinical research activities. A need for stronger global North-South relationships was emphasized, with a focus on improved access to scientific literature, investigational infrastructure, training support, and scholarship opportunities between colleagues in Latin America, North America, and Europe. Indeed, this model between partner institutions in LMICs and HICs has been successful for other orthopaedic groups.[6–9] Additionally, rapid growth of the internet has made the sharing of scientific literature more accessible to orthopaedic surgeons in lower-resourced settings through electronic journals and online repositories. Initiatives such as the Health InterNet Access to Research Initiative (HINARI), a project supported by the World Health Organization, and the Biomed Central (BMC), a United Kingdom-based journal, have provided free access to full-text electronic articles for surgeons in low-income countries.[10] Overall, fostering collaboration between multidisciplinary groups can benefit those in LMICs to overcome barriers and promote locally driven investigative work.

To this end, the Asociación de Cirujanos Traumatólogos de las Américas (Association of Trauma Surgeons in the Americas; ACTUAR) was developed.[11] **(Chapter 3)** The aim of this organization was to promote a collaborative research environment between Latin America and North America, with the goal to improve the clinical care of musculoskeletal trauma through the dissemination of research methodology and development of multi-center studies. ACTUAR has been the mechanism through which Latin American surgeons have been able to organize their successful involvement in multi-national, multi-center studies such as the International Orthopaedic Multi-Center Study in Fracture Care (INORMUS). INORMUS, based primarily at McMaster University and in collaboration with the University of California, San Francisco (UCSF), seeks to document the burden of disease of orthopaedic trauma globally. These types of studies enable the use of evidence-based medicine to guide clinical practice,[12] and are important tools for joint action. Given the small proportion of multi-center studies and the high rate of road traffic fatalities in this region, collaborative initiatives, such as ACTUAR, are a measured solution for better defining and understanding musculoskeletal injury and treatment patterns.[13] Orthopaedic research conducted through the ACTUAR network investigates clinical research questions that are guided by the needs of the Latin American patient populations. Partnering with

researchers in and outside of the region through similar organizations can help to build investigational infrastructure, change clinical practice, and ultimately impact health policy.

Further, non-clinical competencies that promote interprofessional networking as well as organizational and communicative skills are increasingly recognized as beneficial for surgeons. These types of "soft skills" for surgeons have been found to improve patient care.[14–16] Leadership skills and teamwork have shown to have a significant impact on trauma care,[17] leading to decreased time to CT and transfers to the operating room.[18] These same leadership qualities transfer over to a variety of surgeon-led teams, including investigative groups. While many studies recognize the impact that leadership development programs have on physicians in North America, there is a paucity of literature on available leadership development programs in the Latin American region.[19] Orthopaedic surgeons are expected to lead various multi-disciplinary teams and effectively communicate, teach, and facilitate learning, yet few studies have examined the educational leadership needs of orthopaedic trauma surgeons in Latin America. Therefore, a region-specific assessment survey identified the greatest needs and barriers to skills-based leadership development programs for orthopaedic trauma surgeons.[20] **(Chapter 4)** Though the majority (81%) of the surgeon-participants reported that they currently held formal leadership roles in some capacity (hospital, professional society or clinical setting), of which many had more than 20 years' experience in this role, only 18% had reported previously attending a formal leadership development course. Professional ethics, crisis management/organizational change management, and high performing team-building skills were cited as the most important themes. Interestingly, these themes were also perceived as most important by Cuban orthopaedic trauma surgeons in a recent study,[21] confirming the importance of developing and tailoring such programs to specific cohorts of individuals, cultures, professions, and regions.[22,23]

The first leadership development skills course, which included the topics identified in the needs assessment survey, was delivered to orthopaedic surgeons in Hermosillo, Mexico at the National Mexican Orthopaedic and Traumatology Congress (FEMECOT).[24] **(Chapter 5)** All surgeon-leaders who attended the session held national leadership positions across Latin America. This course, as evaluated by the attendees, provided useful knowledge, and was viewed as an effective way to enhance healthcare providers non-clinical skills. It was subsequently used as a model for other such instruction in Latin American countries and can be further used by other orthopaedic trauma surgeons in lower-resourced settings across the region.

Clinical Research: Regional Priorities

Health research can provide solutions to the increasing mortality and morbidity rates in Latin America by better improving health services to those in regions that are disproportionately affected by musculoskeletal conditions, effectively reducing the gaps in care between those in resource-rich and resource-limited settings. Globally, formalized trauma care systems and treatment guidelines are lacking among countries and regions.[25] Critical to these systems and guidelines are the resources needed to deliver musculoskeletal trauma care, which vary in availability regionally.[26] However, the supplies and equipment required to satisfy trauma care guidelines are often only available in HICs, not LMICs.[27,28] In an effort to develop effective guidelines and create treatment standards with resources that are applicable to those in lower-resourced settings, such as in Latin America, the most essential musculoskeletal trauma care resources across diverse resource settings worldwide were identified. **(Chapter 6)** Surgeons,

representing low-, middle-, upper-, and high-income countries, reported no significant differences in ratings for musculoskeletal injury management resources. Consensus was reached by surgeons worldwide on 71 resources considered "most essential", suggesting that these supplies and equipment are locally available across any given setting. These results can be used to establish effective guidelines and treatments standards worldwide.

Notably, government funding in countries across Latin America is substantially low, with only 0.1% to 1% of a country's Gross Domestic Product (GDP) being spent on research for health,[29] causing research priorities in this region to be ill defined.[29] In recognition of this limitation and in an effort to guide future clinical studies within this region, the clinical areas in orthopaedic trauma that are considered the greatest need for research priorities in Latin America were evaluated.[30] **(Chapter 7)** Open fracture management was found to be one of the major unmet areas of interest, including the determination of optimal protocols for initial and definitive open fracture treatment that include issues such as treatment timing, antibiotic prophylaxis, irrigation and debridement, fixation, and wound coverage.

Open Tibial Shaft Fractures: Current Management

The management of open tibial shaft fractures was recently defined as one of the top health research priorities in Latin America.[30] These injuries, caused by high-energy trauma and among the most problematic of orthopaedic injuries in the region, have high rates of incidence from road traffic injuries and poor outcomes associated with soft-tissue defects. In Latin America, more than 50,000 open fractures per year occur in some countries, and complication rates reach as high as 25% in Gustilo Anderson (GA) Type III fractures.[31–33] Despite these staggering figures, open fracture management in Latin America is poorly understood, making it difficult to create treatment standards and advocate for necessary resources. With a goal of characterizing the treatment standards and patterns of open tibia fractures in this region, the current management of isolated open tibia fractures throughout Latin America sites was analyzed.[26] **(Chapter 8)** Identifying treatment patterns for open tibia fractures will lay the groundwork for the potential implementation of best practices.

In addition, there is a need for plastic and reconstructive surgery for these traumatic injuries.[34] Severe soft-tissue wound defects associated with open tibia fractures have negative socioeconomic impacts,[35] with major complications that include infection, nonunion, amputation, and death.[36] In HICs, multidisciplinary management between plastic and orthopaedic surgery teams for soft-tissue reconstruction (flap) procedures and fracture stabilization is common for such injuries.[37] However, in LMICs across Latin America, plastic surgeons are less likely to be the primary soft-tissue coverage provider for GA Type IIIB fractures requiring flap coverage,[38] requiring orthopaedic surgeons to perform these procedures. Exacerbating this issue, most orthopaedic surgeons do not receive training on soft-tissue coverage.[26] In order to determine the Latin American orthopaedic trauma surgeons' current management of soft-tissue coverage practices of open tibia fractures, provide region-specific knowledge gaps, and support the need for better allocation of surgical tools and resources for flap procedures, the treatment of soft-tissue defects following open fractures in the region were examined.[38] **(Chapter 9)**

Open tibia diaphyseal fractures, the most common open long bone injury, contribute to a growing epidemic in this region.[39,40] However, few comprehensive observational studies have reported on the current state of open tibia fractures in Latin America.[13] It is challenging to address orthopaedic care gaps without understanding current treatment protocols and epidemiology of such injuries. The management of open tibia fractures across Latin American countries assessing the clinical outcomes and health-related predictors of quality of life at one-year was prospectively studied. **(Chapter 10)** Given the size of Latin America's population, which is almost double that of the United States and Canada combined,[13] utilizing a prospective observational multi-center study design allowed for the collection of a larger sample size of epidemiological data that can improve generalizability in a patient population.[41] Providing evidence-based guidelines that address the diverse resource settings faced in Latin America can help prevent major complications following injuries and provide critical information for orthopaedic surgeons that can be applied in the Global South.

Open Tibial Shaft Fractures: Interventions

Adequate coverage of the open tibia fracture site is critical for wound healing and optimal limb function. Flap procedures do not necessarily require technologically advanced or expensive equipment, and often are possible to treat with locally-available resources and in the absence of plastic surgery expertise.[42] In a response to the shortage in subspecialty care and soft-tissue training for orthopaedic surgeons in many LMICs across Latin America,[43] sustainable surgical-skills training courses that teach limb-saving, soft-tissue coverage techniques have been developed. Specifically geared towards orthopaedic surgeons in LMICs, these courses have been shown to be effective, reportedly impacting surgeons performance and comfort level with flap procedures.[44,45] The efficacy of a two-day soft-tissue coverage course delivered for orthopaedic trauma surgeons in Latin America assessed the implementation of this type of training.[46] **(Chapter 11)** Such courses can provide for an effective model for training in other Latin American countries.

The economic and demographic characteristics of countries across Latin America are diverse, and large disparities in development exist.[29] Many Latin American countries are predisposed to conditions that are often found in countries with much lower GDPs, posing challenges such as a lack of access to resources, shortages in specialists, and overburdened health systems. Argentina, for example, has one of the largest economies and one of the highest healthcare expenditures per capita in the region,[29] yet significant inequalities in access to healthcare services and varying levels of orthopaedic surgical care exist between provinces.[47] In an effort to address potential regional differences in the management of open tibia fractures, treatment patterns were examined to assess the extent of standardized care across provinces in Argentina. Further, the effectiveness of an educational intervention initiated by the national orthopaedic trauma society, which sought to promote national standardization of orthopedic trauma care, was examined. **(Chapter 12)** The overarching goal was to standardize treatment care and achieve best practices for the management of open tibia fractures across diverse resource settings in Latin America.

Future Directions

The body of work presented in this thesis described aspects of the burden of musculoskeletal trauma, orthopaedic trauma surgeons' capacity for developing skills to better address locally-relevant questions, and gaps in resources needed to provide the necessary care for post-traumatic musculoskeletal injuries. Future work is needed to bridge the gap between the findings presented and their successful implementation, particularly in the standardization of open tibia treatment practices through the establishment of formal guidelines and policies.

Many of the studies included in this thesis highlighted a broader, regional, or global overview of the relevant questions. However, the number of survey respondents is small relative to the number of practicing orthopaedic surgeons in Latin America and does not necessarily reflect conditions within all subregions. A closer evaluation of open tibia treatment patterns from each country within Latin America, with larger sample sizes, could facilitate a more in-depth understanding of the gaps in practice. Subsequently, findings that are specific to each country in Latin America could aid in the development of more accurate treatment guidelines and best practices. As an example, Chapter 6 used the modified Delphi design to determine opinion consensus from one surgeon-expert per country. While this provided for a broader overview worldwide, it is difficult to extrapolate these findings to a more limited local level, particularly in locations with diverse resources. Additionally, within countries with larger populations and economies, such as Argentina, Brazil, and Mexico, there are often significant scales of economies that also make broader results even more difficult to apply. Studies that used an open survey technique, including some in this thesis, have the potential to disproportionately represent one country relative to another; a significant difference in the number of survey responses collected from each country could make it more difficult to apply results universally. Therefore, future work should augment the current studies by concentrating the focus on more narrow areas of interest and regions.

The studies presented in this thesis showed that there was value in skill development. However, the results reflected shorter-term assessments, and therefore, longer-term evaluations are needed. Post-course evaluations that measure knowledge retention and practice-changing behavior, as observed following a soft-tissue reconstruction surgical skills training course for example, would be useful to determine long-term impact of the interventions. Further, course reach could be expanded through an on-line delivery, such as the leadership development training offerings, but on-line learning efficacy would need to be determined, as a main feature of the course is interactive.

Finally, treatment guidelines for the management of injuries, such as open tibia fractures, are significantly lacking throughout Latin American countries[26] and have yet to be formally established on a regional level. A follow up study on the most essential musculoskeletal trauma care resources particularly for Latin American countries could be conducted to develop effective setting-specific guidelines and create best practice treatment standards. Further, these results could be used by national academic societies to support the development of best practice guidelines and advocate for standard resource availability.

References

1. Falavigna A, Filho DEM, Avila JMJ, Guyot JP, Gonzáles AS, Riew DK. Strategy to Increase Research in Latin America: Project on Education in Research by AOSpine Latin America. *Eur J Orthop Surg Traumatol*. 2015;25(1):13-20.
2. Evaniew N, Godin K, Schemitsch EH, Bhandari M. Evidence Gaps in the Global Decade of Road Traffic Safety. *J Orthop Trauma*. 2014;28(6):S15-7.
3. Challa S, Wu HH, Cunningham BP, et al. Orthopaedic Trauma in the Developing World: Where Are the Gaps in Research and What Can Be Done? *J Orthop Trauma*. 2018;32:S43. doi:10.1097/BOT.0000000000001293
4. Urrutia J, Zamora T, Prada C. The Fifty Most Cited Latin American Articles in the Orthopaedic Literature. *Int Orthop*. 2014;38(8):1723-1729.
5. Chomsky-Higgins K, Miclau TA, MacKechnie MC, Aguilar D, Rubio Avila J, Baldy dos Reis F, et al. Barriers to Clinical Research in Latin America. *Front Public Health*. 2017;5:57. doi:10.3389/fpubh.2017.00057
6. O'Brien P, Kajja I, Potter JM, O'Hara NN, Kironde E, Petrisor B. Role of North-South Partnership in Trauma Management: Uganda Sustainable Trauma Orthopaedic Program. *J Orthop Trauma*. 2018;32(10):S21-S24.
7. Conway DJ, Coughlin R, Caldwell A, Shearer D. The Institute for Global Orthopedics and Traumatology: A Model for Academic Collaboration in Orthopedic Surgery. *Front Public Health*. 2017;5:146.
8. Anderson LA, Bernthal NM, Haller JM, Higgins TM, Elliott IS, Anderson DR. Partnership in Ethiopia: University of Utah's and UCLA's Departments of Orthopaedics Collaboration with Soddo Christian Hospital in Ethiopia. *J Orthop Trauma*. 2018;32(10):S12-S15.
9. Major Extremity Trauma Research. Building a Clinical Research Network in Trauma Orthopaedics: The Major Extremity Trauma Research Consortium (METRC). *J Orthop Trauma*. 2016;(30):353-361.
10. Shahryar N, Wright JG, Howard A, et al. Global Access to Literature on Trauma. *Clin Orthop Relat Res*. 2008;466(10):2418-2421.
11. Miclau T, MacKechnie MC, Shearer DW, ACTUAR group. Asociación de Cirujanos Traumatólogos de las Américas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018;32 Suppl 7:S8-S11. doi:10.1097/BOT.0000000000001302
12. INORMUS Investigators. International Orthopaedic Multicentre Study (INORMUS) in Fracture Care: Protocol for a Large Prospective Observational Study. *J Orthop Trauma*. 2015;29 Suppl 10:S2-S6.
13. Moraes VY, Belloti JC, Faloppa F, Bhandari M. Collaborative Multicenter Trials in Latin America: Challenges and Opportunities in Orthopaedic and Trauma Surgery. *Sao Paulo Med J*. 2013;(131):187-192.
14. Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T, et al. Health Professionals for a New Century: Transforming Education to Strengthen Health Systems in an Interdependent World. *Lancet*. 2010;376:1923-1958.
15. Reinertsen JL. Physicians as Leaders in the Improvement of Health Care Systems. 1998;128:833-838.
16. Angood P, Birk S. The value of physician leadership. *Physician Exec*. 2014;40:6-20.
17. Ford K, Menchine M, Burner E, Arora S, Inaba K, Demetriades D, et al. Leadership and Teamwork in Trauma and Resuscitation. *West J Emerg Med*. 2016;XVII(5):539-556.
18. Capella J, Smith S, Philip A, et al. Teamwork Training Improves the Clinical Care of Trauma

Patients. *J Surg Educ*. 2010;67(6):439-443.
19. MacKechnie MC, Miclau TA, Cordero DM, Tahir P, Miclau T. Leadership Development Programs for Healthcare Professionals in Low-and Middle-Income Countries: A Systematic Review. *Int J Health Plann Mgmt*. 2022;37(4):2149-2166.
20. MacKechnie MC, MacKechnie MA, Van Lieshout EMM, et al. Leadership Development for Orthopaedic Surgeons in Latin America: Opportunities for and Barriers to Skill Acquisition. *OTA Int*. Published online 2021. In Press
21. Oberlohr VT, Tabares Neyra H, MacKechnie MC, Flores M, Ceballos AM, Martínez PV. [Evaluation of the Leadership Course for Orthopaedic Surgeons in Cuba]. *Rev Cuba Ortop Traumatol*. 2023;37(1):625-633.
22. Mano MS, Gomes R, Werutsky G, et al. Cross-Cultural Validity Study of a Medical Education Leadership Competencies Instrument in Latin American Physicians: A Multinational Study. *J Glob Oncol*. 2019;5:1-9. doi:10.1200/JGO.19.00243
23. Citaku F, Violato C, Beran T, et al. Leadership Competencies for Medical Education and Healthcare Professions: Population-Based Study. *BMJ Open*. 2012;2(e000812):1-9.
24. MacKechnie MC, Padilla Rojas LG, De la Huerta F, López Almejo L, Gómez JM, Quintero Hernandez S, et al. [Building Leadership Development Capacity for Orthopaedic Surgeons in Latin America]. *Orthotips*. 2021;17(4):211-216.
25. Miclau T, Hoogervorst P, Shearer DW, El Naga A, Working Z, Martin C, et al. Current Status of Musculoskeletal Trauma Care Systems Worldwide. *J Orthop Trauma*. 2018;32 Suppl(7):S64-70.
26. Albright PD, MacKechnie MC, Roberts HJ, Shearer DW, Padilla Rojas LG, Quintero JE, et al. Open Tibial Shaft Fractures: Treatment Patterns in Latin America. *J Bone Jt Surg*. 2020;00(e1):1-10. doi:http://dx.doi.org/10.2106/JBJS.20.00292
27. LaGrone L, Riggle K, Joshipura M, et al. Uptake of the World Health Organization's Trauma Care Guidelines: A Systematic Review. *Bull World Health Organ*. 2016;(94):585-98C.
28. Choi J, Carlos G, Nassar AK, Knowlton LM, Spain DA. The Impact of Trauma Systems on Patient Outcomes. *Curr Probl Surg*. 2021;58:1-21.
29. Moloney, A. Latin America faces hurdles in health research. *The Lancet*. 2009;374:1053-1054. doi:https://doi.org/10.1016/S0140-6736(09)61688-3
30. Roberts HJ, MacKechnie MC, Shearer DW, Segovia Altieri J, de la Huerta F, Rio MW, et al. Orthopaedic Trauma Research Priorities in Latin America: Developing Consensus Through a Modified Delphi. *J Bone Jt Surg Am*. Published online ePub ahead of print 2021.
31. Fraser B. Traffic Accidents Scar Latin America's Roads. *Lancet*. 2005;366(9487):703-704.
32. Orihuela-Fuchs VA, Fuentes-Figuroa S. Infection rate in open fractures adjusted for the degree of exposure. *Acta Ortop Mex*. 2013;27(5):293-298.
33. Pollak AN, Jones AL, Castillo RC, et al. The Relationship Between Time to Surgical Debridement and Incidence of Infection after Open High-Energy Lower Extremity Trauma. *J Bone Jt Surg Am*. 2010;(92):7-15.
34. Borrelli MR. What is the Role of Plastic Surgery in Global Health? A Review. *World J Plast Surg*. 2018;7(3):275-282.
35. Holler JT, MacKechnie MC, Albright PD, Morshed S, Shearer DW, Terry MJ. The impact of inadequate soft-tissue coverage following severe open tibia fractures in Tanzania. *Plast Reconstr Surg*. 8(12):e3272.
36. Gosselin RA, Spiegel DA, Coughlin RR, Zirkle LG. Injuries: The Neglected Burden in Developing Countries. *Bull World Health Organ*. 2009;87(4):246-247.

37. Kuripla C, Tornetta P III, Foote CJ, Koh J, Sems A, Shamaa T, et al. Timing of Flap Coverage with Respect to Definitive Fixation in Open Tibia Fractures. *J Orthop Trauma*. 2021;35(8):430-436.
38. MacKechnie MC, Flores MJ, Giordano V, Terry MJ, Garuz M, Lee N, et al. Management of Soft-Tissue Coverage of Open Tibia Fractures in Latin America: Techniques, Timing, and Resources. *Injury*. 2022;53(4):1422-1429.
39. Court-Brown CM, Rimmer S, Prakash U, et al. The Epidemiology of Open Long Bone Fractures. *Injury*. 1998;29:529-534.
40. Johal H, Schemitsch E, Bhandari M. Why a Decade of Roaf Traffic Safety? *J Orthop Trauma*. 2014;28 Suppl 1:S8-S10.
41. Sprague S, Matta JM, Bhandari M, Anterior Total Hip Arthroplasty Collaborative (ATHAC) Investigators, Dodgin D, Clark CR, et al. Multicenter Collaboration in Obervational Research: Improving Generalizability and Efficiency. *J Bone Jt Surg Am*. 2009;91 Suppl 3:80-86.
42. Semer NB, Sullivan SR, Meara JG. Plastic Surgery and Global Health: How Plastic Surgery Impacts the Global Burden of Surgical Disease. *Reconstr Aesthet Surg*. 2010;63:1244-1248.
43. McDermott FD, Kelly ME, Warwick A, Arulampalam T, Brooks AJ, Gaarder t, Cotton BA, Winter DC. Problems and Solutions in Delivering Global Surgery in the 21st Century. *Br J Surg*. 2015;103(3):165-169.
44. Grimes CE, Bowman KG, Dodgion CM, Lavy CB. Systematic Review of Barriers to Surgical Care in Low-Income and Middle-Income Countries. *World J Surg*. 2011;(35):941-950.
45. Challa S, Conway D, Wu Hao Hua, et al. Can a Two-Day Course Teach Orthopaedic Surgeons Rotational Flap Procedures? An Evaluation of Data From the Nepal SMART Course Over Two Years. *J Orthop Trauma*. 2018;32 Suppl(7):S38-S42.
46. Wu HH, Kushal PR, Caldwell AM, Coughlin RR, Hansen SL, Carey JN. Surgical Management and Reconstruction Training (SMART) Course for International Orthopedic Surgeons. *Ann Glob Health*. 2016;82(4):652-658.
47. Albright PD, MacKechnie MC, Jackson JH, Chopra A, Holler JT, Flores Biard A, et al. Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An] Analysis of Participants in an Orthopaedic Surgical Skills Training Course in Mexico. *OTA Int*. 2019;2(4):e044.
48. Palacios A, Espinola N, Rojas-Roque C. Need and Inequality in the Use of Health Care Services in a Fragmented and Decentralized Health System: Evidence for Argentina. *Int J Equity Health*. 2020;19(67):1-48.

CHAPTER 14

14

Summary and Summary in Dutch

Summary

Each chapter progressed towards addressing the three major objectives in the thesis. **Chapter 1** provided a general introduction on the Global Burden of Disease, with a focus on the large subset of musculoskeletal-related injuries in Latin America and the significant lack of region-specific clinical research studies targeting this population.

The first objective was to identify barriers relevant to clinical research and non-clinical opportunities in Latin America.

In line with this, **Chapter 2** identified the reasons behind knowledge gaps in the literature, addressing musculoskeletal-related injuries in Latin America, despite this region having one of the largest rates of musculoskeletal conditions that contribute to the Global Burden of Disease resulting from trauma. Approximately half of the orthopaedic surgeons that were surveyed reported current involvement in research initiatives but cited potential reasons for decreased productivity. Barriers such as lack of robust investigational infrastructure, lack of evidence-based knowledge, and lack of funding were reported. Clinical research support staff and financial aid were identified as two factors that could increase research capacity at local institutions. Strategies to overcome these perceived obstacles included collaboration between "more developed" (global North) and "less developed" (global South) organizations, increased access to scientific journals, establishment of clinical databases, and scholarship opportunities. Taking into account the perceived barriers and facilitators to incentivize participation in research, the work described in **Chapter 3** outlined a potential solution to address these issues through a multi-national consortium, the Association of Trauma Surgeons in the Americas (Asociación de Cirujanos Traumatólogos de las Américas; ACTUAR). This global North-South organization, centrally organized at the University of California, San Francisco (UCSF) in the United States, promotes collaborative investigative work across Latin American institutions to address critical treatment questions guided by Latin American patient populations. A research symposium held at the annual meeting of the National Mexican Orthopaedic and Traumatology Congress (Federación Mexicana de Colegios de Ortopedia y Traumatología; FEMECOT) is one offering provided through ACTUAR, which teaches the principles of clinical research methodologies and protocols. Further, financial scholarships have been made available through ACTUAR. Overall, this network supports the sharing of scientific information to advance clinical care of musculoskeletal injuries in Latin America and has led to a number of collaborative publications.

Chapter 4 described the paucity of available leadership development training for orthopaedic trauma surgeons' non-clinical skills. Despite recognition of non-clinical leadership skills being effective tools for surgeons' personal and professional success, no studies assessed educational leadership needs on these topics for orthopaedic trauma surgeons in Latin America. A needs assessment of 144 orthopaedic trauma surgeons showed that while almost half of the group (49%) had more than 20 years of experience, 63% reported never having attended a leadership course, with almost all (97%) expressing an interest in attending such training. The main barriers cited were lack of invitations, difficulty missing work, and cost.

As a solution, **Chapter 5** described the creation and delivery of the first-of-its-kind leadership development program in Mexico, using the curriculum designed specifically to the interests and needs reported by the Latin American orthopaedic trauma surgeons. The goal of the course was

to enrich surgeons' development of non-clinical leadership skills, increase their knowledge of leadership concepts and principles, facilitate networking, reinforce Global North-South partnerships, and ultimately advance high-quality musculoskeletal care.

Conclusions:

- Reported barriers to clinical research among Latin Americans included a lack of investigational infrastructure, evidence-based medicine knowledge, and financial support. There was complete agreement among participants that research capacity and interest would improve if structural and economic support were available.
- Through a global North-South collaboration (ACTUAR), Latin American orthopaedic trauma surgeons have increased collaboration with likeminded individuals interested in building research capacity and sharing resources. The group identified open tibia fracture management to target as an initial multi-center collaborative pilot project.
- One hundred and forty-four orthopaedic trauma surgeons from 18 countries across Spanish-speaking and Portuguese-speaking Latin America identified professional ethics, crisis management/organizational management, and high performing team-building skills as the most important leadership development themes. Eighty-one percent of surgeon-participants self-reported holding leadership roles, but 63% had never attended a leadership course due to lack of invitations, difficulty missing work, and cost. Almost all participants (97%) expressed interest in attending a leadership course designed for their surgical specialty.
- Course curriculum was developed based on the needs assessment for orthopaedic trauma surgeons, and the first Latin American leadership development course was delivered to surgeons free of cost at the FEMECOT conference in Mexico.

The second objective of the thesis was to define clinical needs, clinical research priorities, and explore the management of open tibia fractures across the region.

Chapter 6 sought to broadly identify the most critical resources needed to support musculoskeletal trauma care worldwide. The findings, which can be used to develop guidelines for care, underscored the need to prioritize resources that are locally available across diverse resource settings. Using a modified Delphi study design, 103 orthopaedic surgeons, representing low-and middle-income countries (LMICs), upper-middle income countries (UMICs), and high-income countries (HICs), established consensus on 71 resources considered most important for pre-, in-, and post-hospital care. These resources were associated with a variety of categories, such as ancillary services, personnel, training, protocols, infrastructure, and supplies and equipment. Examples of the most essential resources included anesthesiologists, orthopaedic surgeons, quick response teams, blood banks, reliable power supply, trauma management protocols, pre-operative anesthesia assessment protocol, power equipment, intubation supplies, and traction tables.

Chapter 7 similarly used a modified Delphi approach to examine the most important clinical research priorities in Latin America, identified by orthopaedic trauma surgeons across the region. Six clinical questions reached consensus, establishing the following topics as top health research priorities: open fractures, geriatric hip fractures, polytrauma, pelvic and acetabular fractures, and musculoskeletal infections. With open fracture management being considered as a top health

research priority in Latin America, **Chapter 8** detailed one of the first studies to characterize open tibia fracture treatment patterns on a regional level. Of the 616 participants from 20 national orthopaedic societies who completed the survey, only 26.5% reported having formalized treatment guidelines for open tibia fractures at their institutions. Regarding antibiotics, 34.6% of surgeons administered antibiotics more than three hours after patient presentation to the hospital. For irrigation and debridement, 53.9% reported treating these fractures between 6 to 24 hours after arrival to the hospital due to lack of operative personnel or rooms. Primary closure was performed most frequently (87.5%), but 31.5% of GA Type IIIB fractures did not receive soft-tissue coverage due to lack of either plastic surgical support or surgeon training to perform flaps. Finally, 29.6% of respondents reported patients presenting to their hospitals greater than 24 hours post-injury. Treatment patterns were also compared between surgeons from MICs to HICs to better understand the differences in management across income groups and showed that delayed internal fixation ($p<0.001$) and primary closure ($p<0.001$) were performed more commonly by surgeons in MICs than HICs.

Chapter 9 further assessed open tibia fracture treatment, with a focus on soft-tissue wound management. The survey was completed by 469 surgeons in Latin America and showed that only 44% had prior soft-tissue training. Plastic surgeons were the primary providers for soft-tissue coverage for GA Type IIIB fractures more commonly in HICs than in MICs ($p<0.01$) and were available more commonly (within 24 hours) in HICs than MICs ($p=0.05$). In general, orthopaedic surgeons in HICs had more access to plastic surgeons at their institutions than those in MICs, and it affected the type of flap chosen for lower extremity defects; free flaps were performed more commonly in HICs than MICs for proximal third ($p<0.01$), middle third ($p=0.02$), and distal third ($p<0.01$) lower extremity defects. Further, for wound coverage resources, only negative pressure wound therapy (NPWT or Wound VAC) was available to more than half of the respondents. Finally, **Chapter 10** prospectively evaluated the management of 288 open tibia diaphyseal fractures through an observational study to assess predictors of clinical outcomes in health-related quality of life (HRQOL) following open tibia fractures at one-year. Using the SF-12, the primary outcome measure was the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores. For PCS, there was a significant quality of life impact on those that sustained a firearm-related injury (estimate: -8.5, 95% CI (-14.4 – -2.5)) or an OTA arterial score 3 injury (estimate: -16.5, 95% CI (-30.5 – -2.6)). For MCS, delays in timing from injury to hospital (estimate per hour: -0.07, 95% CI (-0.1 – -0.02)) were associated with a decrease in HRQOL and external fixation at initial stabilization was associated with a reduced mental quality of life at one-year when compared to intramedullary fixation (estimate: -3.0, 95% CI (-5.8 – -0.7). Only 47.2% of patients received definitive fixation at the time of their initial treatment, which included intramedullary nailing (35.8%), non-operative management with splinting/casting (33.7%), and external fixation (28.1%).

Conclusions:

- A total of 308 unique resources for pre-, in-, and post-hospital phases of care were identified, of which 71 resources achieved consensus as most essential for musculoskeletal trauma care across any given setting worldwide. There was a significant difference ($p<0.0167$) in ratings between income groups (LMICs, UMICs, and HICs) for 16 resources, all of which were related to general trauma care rather than musculoskeletal injury management.

- Open fractures were identified as a top clinical research priority in Latin America, specifically, examining the optimal protocol for timing, antibiotics, fracture fixation, and wound coverage at various hospital levels across the region.
- Open tibia fracture treatment patterns showed differences between MICs and HICs regarding delayed internal fixation (53.3% vs. 22.0%, p<0.001) and primary closure (88.9% vs. 62.8%, p<0.001) for GA Type I and II fractures. Almost one-third (31.5%) of GA Type IIIB fractures did not receive soft-tissue coverage and only 26.5% of the 616 survey respondents from 20 Latin American countries reported having formalized treatment guidelines for open tibia fractures at their institutions.
- Access to soft-tissue coverage providers was different between income groups (HICs and MICs). Plastic surgeons were the primary provider for GA Type IIIB fractures more commonly in HICs than in MICs (100% vs. 47%, p<0.01) and were available more commonly (<24 hours) in HICs than MICs (63% vs. 26%, p=0.05). Free flaps were performed more commonly in HICs than MICs for proximal third (55% vs. 10%, p<0.01), middle third (36% vs. 9%, p=0.02), and distal third (55% vs. 10%, p<0.01) lower extremity defects.
- External fixation at initial stabilization was associated with a reduced mental quality of life at one-year when compared to intramedullary fixation (estimate: -3.2, 95% CI (-5.5 – -0.8)) and there was a significant physical quality of life impact on those that sustained a firearm-related injury (estimate: -8.2, 95% CI (-14.2 – -2.1)) or Type III OTA arterial subcategory injury (estimate: -3.0, 95% CI (-30.9 – -2.6)). Only 47.2% of patients received definitive fixation at the time of their initial treatment, with intramedullary nailing (35.8%) being the most common method.

The final objective of the thesis was to address the treatment of open tibia fractures by developing potential interventions to surgical care and the development of best practice guidelines, taking into account the low-and-middle income countries' (LMICs) resource-limited settings in Latin America.

With limited soft-tissue coverage training opportunities, lack of specialists in MICs providing flap procedures, and lack of soft-tissue coverage being performed on GA Type IIIB fractures due to institutional barriers, **Chapter 11** described the efficacy of the Surgical Management and Reconstructive Training (SMART) Course, a soft-tissue surgical skills training as an educational intervention for Latin American orthopaedic surgeons. A pre- and post-course knowledge test showed that overall scores improved (p=0.005), particularly on the plastic surgery component (p=0.003). On the needs assessment, 51.9% did not feel comfortable designing or choosing the correct flap for a patient. The majority of participants (61.1%) reported that flaps were uncommonly performed in their hospitals. Barriers to performing flaps included lack of subspecialist care, lack of resources such as dermatomes, and poor institutional and peer support. This training course could serve as an educational model for orthopaedic surgeons in other LMICs in the absence of plastic surgeons. **Chapter 12** evaluated the level of standardization of open tibia fracture management across Argentina's diverse regional settings, with the goal to achieve best practices throughout the country. The Argentine Association of Trauma and Orthopaedics (AATO), seeking to attain improvements in care throughout the country, developed an "Exterior Committee", based in Buenos Aires, and an "Interior Committee", comprising surgeons practicing in outlying provinces across Argentina. Notably, results showed

that wound coverage procedures for GA Type IIIB injuries were more commonly treated by orthopaedic surgeons in the interior versus the exterior regions (p=0.004), with greater rates of definitive wound coverage within seven days post-injury reported in comparison to those in the exterior (p=0.009). These findings seem paradoxical; typically decreased access to plastic surgeons in more peripheral, rural settings would seem to lead to greater delays to soft-tissue coverage. However, given the results of fewer delays, one possible explanation is that reliance on plastic surgeons' availability may cause greater delays than the orthopaedic surgeons performing the procedures themselves. This supports the concept of enhanced soft-tissue coverage training for orthopaedic surgeons. This type of intervention may be a model for future trainings sponsored by other national orthopaedic societies.

Conclusions:

- The SMART Course is effective in improving the level of knowledge and comfort in performing flaps for orthopaedic surgeons. A pre- and post-course test showed that knowledge-based scores improved (39.6% to 53.6%, p=0.005). Additionally, institutional and physician barriers to performing flaps were reported, many of which were modifiable through training programs such as the SMART Course.
- Treatment patterns were identified across provinces in Argentina for open tibia fracture management, however, differences were reported in soft-tissue procedures. Surgeons in the more rural, less-resourced interior of the country more commonly performed flap procedures (0% vs. 35%, p=0.004) than those in the urban, greater-resourced exterior of the country, with greater rates of definitive wound coverage within seven days post-injury (32% vs. 74%, p=0.009).

Chapter 13 provided a general discussion on the overall findings and future directions.

Nederlandse samenvatting

Elk hoofdstuk behandelt een van de drie belangrijkste doelstellingen van het proefschrift. **Hoofdstuk 1** gaf een algemene inleiding over de wereldwijde ziektelast, met de nadruk op de grote groep van musculoskeletale letsels in Latijns-Amerika en het aanzienlijke gebrek aan regiospecifiek klinisch onderzoek gericht op deze populatie.

De eerste doelstelling was het identificeren van belemmeringen die relevant zijn voor klinisch onderzoek en niet-klinische kansen in Latijns-Amerika.

In overeenstemming hiermee identificeerde **Hoofdstuk 2** de redenen achter kennislacunes over musculoskeletale letsels in Latijns-Amerika in de literatuur, ondanks het feit dat deze regio een van de grootste percentages musculoskeletale aandoeningen heeft die bijdragen aan de wereldwijde ziektelast door trauma. Ongeveer de helft van de responderende orthopedisch chirurgen gaf aan momenteel betrokken te zijn bij onderzoeksinitiatieven, maar noemde mogelijke redenen voor verminderde productiviteit. Andere genoemde belemmeringen waren een gebrek aan robuuste onderzoeksinfrastructuur, gebrek aan op feiten gebaseerde kennis en gebrek aan financiering. Ondersteunend personeel voor klinisch onderzoek en financiële ondersteuning werden geïdentificeerd als twee factoren die de onderzoekscapaciteit bij lokale instellingen zouden kunnen vergroten. Strategieën om deze waargenomen obstakels te overwinnen, waren onder meer samenwerking tussen "meer ontwikkelde" (mondiale noorden) en "minder ontwikkelde" (mondiale zuiden) organisaties, betere toegang tot wetenschappelijke tijdschriften, het opzetten van klinische databases en mogelijkheden voor beurzen. Rekening houdend met de ervaren belemmeringen en facilitators om deelname aan onderzoek te stimuleren, schetste het in **Hoofdstuk 3** beschreven werk een mogelijke oplossing om deze problemen aan te pakken via een multinationaal consortium, de Association of Trauma Surgeons in the Americas (Asociación de Cirujanos Traumatólogos de las Amerika; ACTUAR). Deze wereldwijde Noord-Zuid-organisatie, centraal georganiseerd aan de Universiteit van Californië, San Francisco (UCSF) in de Verenigde Staten, promoot gezamenlijk onderzoekswerk in Latijns-Amerikaanse instellingen om kritische behandelingsvragen aan te pakken, geleid door Latijns-Amerikaanse patiëntpopulaties. Een jaarlijks onderzoekssymposium tijdens het landelijk jaarcongres van de Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT) is een aanbod dat wordt aangeboden via ACTUAR, dat onderwijs geeft over de principes van klinische onderzoeksmethoden en -protocollen. Verder zijn er financiële beurzen beschikbaar gesteld via ACTUAR. Over het algemeen ondersteunt dit netwerk het delen van wetenschappelijke informatie om de klinische zorg voor letsels van het steun- en bewegingsapparaat in Latijns-Amerika te bevorderen. Dit heeft tot een aantal gezamenlijke publicaties geleid.

Hoofdstuk 4 beschreef het gebrek aan beschikbare leiderschapsontwikkelingstrainingen voor de niet-klinische vaardigheden van orthopedisch traumachirurgen. Ondanks de erkenning dat niet-klinische leiderschapsvaardigheden effectieve hulpmiddelen zijn voor het persoonlijke en professionele succes van chirurgen, zijn er geen studies die de educatieve behoeften aan leiderschap over deze onderwerpen voor orthopedisch traumachirurgen in Latijns-Amerika hebben beoordeeld. Uit een behoefteonderzoek onder 144 orthopedisch traumachirurgen bleek dat ondanks het feit dat bijna de helft van de groep (49%) meer dan 20 jaar ervaring had, 63% aangaf nog nooit een leiderschapscursus te hebben gevolgd, waarbij bijna iedereen (97%)

interesse toonde om deel te nemen zo'n opleiding. De belangrijkste genoemde belemmeringen waren het gebrek aan uitnodigingen, de moeilijkheid om werk te missen en de kosten.

Als oplossing beschrijft **Hoofdstuk 5** de opzet en beschikbaar maken van een eerste leiderschapsontwikkelingsprogramma in Mexico, waarbij gebruik werd gemaakt van het curriculum dat specifiek was ontworpen voor de interesses en behoeften die door de Latijns-Amerikaanse orthopedische traumachirurgen werden gemeld. Het doel van de cursus was om de ontwikkeling van niet-klinische leiderschapsvaardigheden van chirurgen te verrijken, hun kennis van leiderschapsconcepten en -principes te vergroten, netwerken te vergemakkelijken, Noord-Zuid-partnerschappen te versterken en uiteindelijk hoogwaardige musculoskeletale zorg te bevorderen.

Conclusies:

- Gerapporteerde belemmeringen voor klinisch onderzoek onder Latijns-Amerikanen waren onder meer een gebrek aan onderzoeksinfrastructuur, evidence-based medische kennis en financiële steun. De deelnemers waren het er volledig over eens dat de onderzoekscapaciteit en -interesse zou toenemen als er structurele en fincanciële steun beschikbaar zou zijn
- Door een wereldwijde Noord-Zuid-samenwerking (ACTUAR) hebben Latijns-Amerikaanse orthopedische traumachirurgen de samenwerking versterkt met gelijkgestemde personen die geïnteresseerd zijn in het opbouwen van onderzoekscapaciteit en het delen van middelen. De groep identificeerde de behandeling van open tibiafracturen als een interessant doel voor een eerste, pilot multicenter samenwerkingsproject
- Honderdvierenveertig orthopedisch traumachirurgen uit 18 landen in Spaanstalig en Portugeessprekend Latijns-Amerika voltooiden benoemden beroepsethiek, crisis-/organisatiemanagement en goed presterende teambuilding naar voren als de belangrijkste leiderschapsthema's voor leiderschapsontwikkeling. Eenentachtig procent van de deelnemende chirurgen gaf zelf aan leiderschapsposities te bekleden, maar 63% had nog nooit een leiderschapscursus gevolgd vanwege een gebrek aan uitnodigingen, moeite met het missen van werk en kosten. Bijna alle deelnemers (97%) toonden interesse in het bijwonen van een leiderschapscursus die was ontworpen voor hun chirurgische specialiteit
- Het cursuscurriculum is ontwikkeld op basis van de behoefteanalyse voor orthopedische traumachirurgen, en de eerste Latijns-Amerikaanse cursus voor leiderschapsontwikkeling werd gratis aan chirurgen gegeven tijdens het FEMECOT-congres.

Het tweede doel van dit proefschrift was het identificeren van klinische behoeften, klinisch en regionaal relevante onderzoeksprioriteiten en uiteindelijk het onderzoeken van de behandeling van open tibiafracturen in de hele regiom om een aanzienlijk problematisch regionaal gezondheidsprobleem aan te pakken.

Hoofdstuk 6 had als doel om op hoofdlijnen de meest kritieke middelen te identificeren die nodig zijn voor goede musculoskeletale traumazorg wereldwijd. Deze bevindingen, de gebruikt kunnen worden om richtlijnen voor zorg te ontwikkelen, onderstrepen de noodzaak om prioriteit te geven aan middelen die lokaal beschikbaar zijn in de verschillende inkomensgebieden. Met

behulp van een aangepast Delphi-design bereikten 103 orthopedisch chirurgen, die lage- en middeninkomenslanden (LMIC's), hogere-middeninkomenslanden (UMIC's) en hoge-inkomenslanden (HIC's) vertegenwoordigden, consensus over de 71 belangrijkste randvoorwaarden voor goede pre-, in- en post-hospitale zorg. Deze items werden verdeeld in categorieën, zoals ondersteunende diensten, personeel, training, protocollen, infrastructuur en voorraden en apparatuur. Voorbeelden van essentiële middelen waren onder meer voldoende anesthesiologen, orthopedisch chirurgen en acute zorgteams, toegant tot bloedproducten, betrouwbare stroomvoorziening, protocollen voor trauma opvang, een protocol voor preoperatieve screening door de anesthesist, elektrische apparatuur, intubatiebenodigdheden en tractietafels.

Hoofdstuk 7 gebruikte een vergelijkbare aangepaste Delphi-methode om de belangrijkste klinische researchprioriteiten in Latijns-Amerika te onderzoeken, geïdentificeerd door orthopedische traumachirurgen in de hele regio. Over zes onderwerpen werd consensus bereikt, waarbij open fracturen, geriatrische heupfracturen, polytrauma, bekken- en acetabulumfracturen en musculoskeletale infecties werden geprioriteerd voor onderzoek. Omdat de behandeling van open fracturen wordt beschouwd als een topprioriteit voor gezondheidsonderzoek in Latijns-Amerika, beschrijft **Hoofdstuk 8** een van de eerste studies naar de behandeling van open tibiafracturen op regionaal niveau. Van de 616 deelnemers van 20 nationale orthopedische verenigingen die de enquête hebben ingevuld, gaf slechts 26,5% aan geformaliseerde behandelingsrichtlijnen voor open tibiafracturen in hun ziekenhuis te hebben. Met betrekking tot antibiotica, diende 34,6% van de chirurgen antibiotica pas meer dan drie uur na presentatie van de patiënt in het ziekenhuis toe. Voor irrigatie en debridement gaf 53,9% aan deze fracturen tussen 6 en 24 uur na aankomst in het ziekenhuis te behandelen wegens gebrek aan operatiepersoneel of -kamers. Primaire sluiting werd het vaakst uitgevoerd (87,5%), maar bij 31,5% van de GA Type IIIB-fracturen werd geen weke delen bedekt vanwege een gebrek aan plastische chirurgische ondersteuning of een gebrek aan scholing van de chirurg in het uitvoeren van gesteelde of vrij-gevascularisseerde lappen. Ten slotte meldde 29,6% van de respondenten dat patiënten zich meer dan 24 uur na het ongeval bij hun ziekenhuis meldden. Ook werden behandelingen tussen chirurgen van MIC's naar HIC's vergeleken om de verschillen in tussen inkomensgroepen beter te begrijpen. Dit toonde aan dat uitgestelde interne fixatie ($p<0,001$) en primaire sluiting ($p<0,001$) meer werden gebruikt door chirurgen in MIC's dan in HIC's.

Hoofdstuk 9 gaat verder in op de behandeling van open tibiafracturen, meer specifiek de behandeling van weke-delenletsel. Het vragenlijst werd ingevuld door 469 chirurgen in Latijns-Amerika en toonde aan dat slechts 44% een weke-delentraining had gehad. Plastisch chirurgen voerden het vaakst de weke-delendekking uit voor GA Type IIIB-fracturen. Dat deden zij vaker in HIC's dan in MIC's ($p<0,01$) en ze waren vaker (binnen 24 uur) beschikbaar in HIC's dan in MIC's ($p=0,05$). Over het algemeen hadden orthopedisch chirurgen in HIC's meer toegang tot plastisch chirurgen in hun ziekenhuis dan orthopedisch chirurgen in MIC's, en dit beïnvloedde het type flap dat werd gekozen voor defecten aan de onderste ledematen; vrije lappen werden vaker uitgevoerd bij HIC's dan bij MIC's voor defecten aan het proximale derde ($p<0,01$), middelste derde ($p=0,02$) en distale derde ($p<0,01$) van de onderste extremiteit. Daarnaast was voor wondbedekking alleen negatieve druktherapie (NPWT of Wound VAC) beschikbaar voor meer dan de helft van de respondenten.

Ten slotte evalueerde **Hoofdstuk 10** prospectief de behandeling van 301 open tibia diafysaire fracturen door middel van een observationele studie om voorspellers van klinische uitkomsten in gezondheidsgerelateerde kwaliteit van leven na open tibiafracturen na 1 jaar te identificeren. Met behulp van de SF-12 was de primaire uitkomstmaat Physical Component Summary (PCS) en Mental Component Summary (MCS). Voor PCS was er een significante impact op de kwaliteit van leven van degenen die een vuurwapengerelateerd letsel opliepen (effectmaat: -8.5, 95% CI (-14.4 – -2.5)) of OTA type III arterieel letsel (effectmaat: -16.5, 95% CI (-30.5 – -2.6)). Voor MCS was externe fixatie bij initiële stabilisatie geassocieerd met een verminderde mentale kwaliteit van leven na een jaar in vergelijking met intramedullaire fixatie (effectmaat: 3.0, 95% CI (-5.8 – -0.7)). Slechts 47,2% van de patiënten onderging definitieve fixatie ten tijde van hun initiële behandeling, waaronder een intramedullaire pen (35,8%), niet-operatieve behandeling met spalk/gips (33,7%) en externe fixatie (28,1%).

Conclusies:

- In totaal werden 308 unieke items voor goede musculoskeletale traumazorg in de pre-, per- en post-ziekenhuisfasen van zorg geïdentificeerd. 71 items werden in consensus beschouwd als meest essentieel in elke setting wereldwijd. Er was een significant verschil ($p<0,0167$) in beoordeling tussen inkomensgroepen (LMIC's, UMIC's en HIC's) voor 16 middelen, die allemaal meer betrekking hadden op algemene traumazorg dan op het behandelen van musculoskeletale letsels.
- Open fracturen werden geïdentificeerd als een topprioriteit voor klinisch onderzoek in Latijns-Amerika, met name het onderzoeken van het optimale protocol voor timing, antibiotica, fractuurfixatie en wonddekking op verschillende ziekenhuisniveaus in de regio.
- Behandelprotocollen voor open tibiafracturen verschilden tussen MIC's en HIC's met betrekking tot vertraagde interne fixatie (53,3% vs. 22,0%, $p<0,001$) en primaire sluiting (88,9% vs. 62,8%, $p<0,001$) bij GA Type I en II fracturen. Bijna een derde (31,5%) van de GA Type IIIB-fracturen kreeg geen weke-delendekking en slechts 26,5% van de 616 respondenten uit 20 Latijns-Amerikaanse landen gaf aan geformaliseerde behandelingsrichtlijnen voor open tibiafracturen in hun ziekenhuis te hebben.
- Beschikbaarheid van chirurgen voor weke-delendekking verschilde tussen inkomensgroepen (HIC's en MIC's). Voor GA Type IIIB-fracturen werd die vaker verzorgd door plastisch chirurgen in HIC's dan in MIC's (100% vs. 47%, $p<0,01$) en zij waren vaker binnen 24 uur beschikbaar in HIC's dan in MIC's (63% vs. 26 %, $p=0,05$). Vrije flappen werden vaker uitgevoerd in HIC's dan MIC's bij defecten aan het proximale derde (55% vs. 10%, $p<0,01$), middelste derde (36% vs. 9%, $p=0,02$) en distale derde (55% vs. 10 %, $p<0,01$) van de onderste ledematen.
- Externe fixatie bij initiële stabilisatie ging gepaard met een verminderde mentale kwaliteit van leven na een jaar in vergelijking met directe intramedullaire fixatie (effectmaat: -3.2, 95% CI (-5.5 – -0.8)) en er was een significante impact op de fysieke kwaliteit van leven bij degenen die een vuurwapengerelateerd letsel hebben opgelopen (effectmaat: -8.2, 95% CI (-14.2 – -2.1)) of OTA-subcategorie Type III arterieel letsel (effectmaat: -3.0, 95% CI (-30.9 – -2.6)). Slechts 47,2% van de patiënten kreeg definitieve fixatie op het moment van hun eerste behandeling, waarbij een intramedullaire pen (35,8%) de meest gebruikelijke methode was.

Het laatste doel van dit proefschrift was om de behandeling van open tibiafracturen te onderzoeken door mogelijke interventies voor chirurgische zorg en 'best practice'richtlijnen te ontwikkelen, rekening houdend met de beperkte middelen van de lage- en middeninkomenslanden (LMIC's) in Latijns Amerika.

Tegen de achtergrond van de beperkte trainingsmogelijkheden voor weke-delendekking, het gebrek aan specialisten in MIC's om flapprocedures uit te voeren, en het beperkte aantal weke-delendekkingen dat wordt uitgevoerd bij GA Type IIIB open tibiafracturen als gevolg van barrières in het ziekenhuis, beschrijft **Hoofdstuk 11** de effectiviteit van de Surgical Management and Reconstructive Training (SMART) Course, een training voor chirurgische weke-delen behandeling als educatieve interventie voor Latijns-Amerikaanse orthopedisch chirurgen. Uit een kennistoets voor en na de cursus bleek dat de algemene scores verbeterden (p=0,005), met name op het onderdeel plastische chirurgie (p=0,003). Bij de behoefteanalyse voelde 51,9% zich niet comfortabel bij het ontwerpen of kiezen van de juiste flap voor een patiënt. De meerderheid van de deelnemers (61,1%) meldde dat flappen zelden werden uitgevoerd in hun ziekenhuis. Belemmeringen daarvoor waren onder meer een gebrek aan subspecialistische zorg, gebrek aan middelen zoals dermatomen en slechte institutionele en collegiale ondersteuning. Deze training zou als opleidingsmodel kunnen dienen voor orthopedisch chirurgen in andere LMIC's indien plastisch chirurgen niet beschikbaar zijn.

Hoofdstuk 12 evalueerde het niveau van standaardisatie van de behandeling van open tibiafracturen in verschillende regionale ziekenhuis in Argentinië, met als doel best practices in het hele land te bereiken. De Argentijnse Vereniging voor Trauma en Orthopedie (AATO), die streeft naar verbeteringen in de zorg in het hele land, ontwikkelde een "Exterior Comittee", gevestigd in Buenos Aires, en een "Interior Comittee", bestaande uit chirurgen die in afgelegen provincies in heel Argentinië werkzaam zijn. De resultaten toonden met name aan dat wondbedekkingsprocedures voor GA Type IIIB-verwondingen vaker werden behandeld door orthopedisch chirurgen in het binnenland dan het stedelijk buitengebied (p=0,004), met hogere percentages van definitieve wonddekking binnen zeven dagen na het letsel gerapporteerd in vergelijking met die in het stedelijk buitengebied (p=0,009). Deze bevindingen lijken paradoxaal; verminderde toegang tot plastisch chirurgen in meer perifere, landelijke omgevingen lijkt te leiden tot grotere vertragingen bij de dekking van weke-delen. Een andere verklaring is dat de afhankelijkheid van beschikbare plastisch chirurgen grotere vertragingen kan veroorzaken dan wanneer de orthopedisch chirurgen de procedures zelf uitvoeren. Dit ondersteunt het concept van verbeterde weke-delen bedekkingstraining voor orthopedisch chirurgen. Dit type interventie kan een model zijn voor toekomstige trainingen die worden gesponsord door andere nationale orthopedische verenigingen

Conclusies:

- De SMART Cursus is effectief in het verbeteren van het kennisniveau en comfort bij het uitvoeren van flappen voor orthopedisch chirurgen. Uit een pre- en post-cursus test bleek scores voor kennis verbeterden (39,6% naar 53,6%, p=0,005). Bovendien werden belemmeringen voor ziekenhuizen en artsen voor het uitvoeren van flappen gemeld, die vaak konden worden gewijzigd door middel van trainingsprogramma's zoals de SMART-cursus.

- Behandelpatronen werden geïdentificeerd in verschillende provincies in Argentinië voor de behandeling van open tibiafracturen, maar er werden verschillen gemeld in procedures voor weke-delen. Chirurgen in het meer landelijke binnenland met minder middelen voerden vaker flapprocedures uit (0% vs. 35%, p=0,004) dan die in het stedelijke buitengebied met meer middelen, met hogere percentages definitieve wonden dekking binnen zeven dagen na verwonding (32% vs. 74%, p=0,009).

Hoofdstuk 13 geeft een algemene discussie over de belangrijkste bevindingen en mogelijkheden voor toekomstig onderzoek.

APPENDICES

Appendices

List of Publications

- MacKechnie MC, Shearer DW, Verhofstad MHJ, Martin C, Graham SM, Pesantez R, Huttl T, Schuetz M, Kojima K, Bernstein BP, Miclau T, Delphi Study Group. *J Bone Joint Surg Am.* 2023. Epub ahead of print.

- Brown KE, Flores MJ, MacKechnie MC, Rodarte P, O'Marr J, Shearer DW, Toogood P. Novel e-Learning Platform for Orthopaedic Training in LMICs: A Descriptive Review of the IGOT Portal. *Surg Open Sci*. 2023;13:24-6.

- Oberlohr V, Tabares Neyra H, MacKechnie MC, Flores MJ, Ceballos A, Balmaseda R, Miclau III T, ACTUAR Cuban Leadership Study Group. Evaluation of a Leadership Course for Orthopaedic Surgeons in Cuba. *Rev Cuba de Ortop y Traumatol.* 2023;37(1):625-32.

- Urva M, Cortez A, Katyal T, Shearer DW, Morshed S, Miclau T, MacKechnie MC, Sabharwal S, COACT Study Group. Orthopaedic Trauma Observerships in North America for International Surgeons: The Visitors' Perspective. *OTA Int.* 2023;6(1):e229-36.

- Brown K, Solaiman RH, Flores MJ, Nadone H, MacKechnie MC, Shearer DW, Miclau T. Opportunities for International Orthopaedic Volunteerism: An Exploration of United States and Canada-Based Nonprofit Organizations. *J Bone Joint Surg Am.* 2023;105-A(7):571-7.

- Flores MJ, Brown KE, Pendleton MM, Albright PD, MacKechnie MC, Rodriguez EG, Ramirez C, Pena Martinez VM, Miclau T. Barriers to and Outcomes of Initiating Clinical Research at Two Trauma Centers in Mexico. *J Surg Res*. 2023;(284):1-5.

- MacKechnie MC, Albright PD, Garabano G, Bidolegui F, Pereira S, Pesciallo CA, Miclau T, Argentina Study Group. Open Tibial Shaft Fracture Management in Argentina: An Evaluation of Treatment Standards in Diverse Resource Settings. *OTA Int.* 2022;5(3):e209-16.

- MacKechnie MC*, Garabano G*, Pereira S, Brown K, Flores MJ, Pesciallo CA, Miclau T, Bidolegui F, Study Group. Open Tibial Fracture Treatment in Argentina: Reoperation Rates Following Surgical Management. *J Bone Joint Surg Open Access.* 2022; 7(2). e21.00153

- MacKechnie MC, Miclau TA, Cordero DM, Tahir PM, Miclau T. Leadership Development Programs for Healthcare Professionals in Low-and Middle-Income Countries: A Systematic Review. Int *J Health Plan Mgmt.* 2022;37(4):1-18.

- MacKechnie MC, Flores MJ, Giordano V, Terry MJ, Garuz M, Lee N, Padilla Rojas JG, MacKechnie MA, Bidolegui F, Brown K, Quintero JE, Ding A, Sánchez Valenciano CG,

Tabares Neyra H, Segovia J, Aguilar D, Van Lieshout EMM, Verhofstad MHJ, Miclau T, Study Group. Management of Soft-Tissue Coverage of Open Tibia Fractures in Latin America: Techniques, Timing, and Resources. *Injury*. 2022;2(41):1-8.

- Miclau T, MacKechnie MC, Born CT, MacKechnie MA, Dyer GSM, Yuan BJ, Dawson J, Lee C, Ishmael CR, Schreiber VM, Tejwani NC, Ulmer T, Shearer DW, Agarwal-Harding KJ, Johal H, Khormaee S, Sprague S, Whiting PS, Roberts HJ, Coughlin R, Gosselin R, Rosenwasser MP, Johnson A, Babu JM, Dworkin M, Makhni MC, McClellan T, Nwachuku CO, Miclau E, Morshed S. International Orthopaedic Volunteer Opportunities in Low-and Middle-Income Countries. *J Bone Joint Surg Am*. 2022;104(10):e44-50.

- MacKechnie MC, MacKechnie MA, Van Lieshout EMM, Verhofstad MHJ, Quintero JE, Padilla LG, Tabares Neyra H, Dello Russo B, Giordano V, Vilensky E, Fuehrer SL, Miclau T, and ACTUAR Study Group. Leadership Development for Orthopaedic Trauma Surgeons in Latin America: Opportunities for and Barriers to Skill Acquisition. *OTA Int.* 2021;4(4):e146-52.

- Roberts HJ, MacKechnie MC, Shearer DW, Segovia Altieri J, de la Huerta F, Rio MW, Sánchez Valenciano C, Miclau T and the ACTUAR Study Group. Orthopaedic Trauma Research Priorities in Latin America: Developing Consensus through a Modified Delphi Approach. *J Bone Joint Surg Am*. 2021;103(24):2318-23.

- MacKechnie MC, Padilla Rojas LG, de la Huerta F, Lopez Almejo L, Gomez JM, Quintero Hernandez S, Miclau T. Building Leadership Development Capacity for Orthopaedic Surgeons in Latin America. *Orthotips*.2021;17(4):57-62.

- MacKechnie MC, Albright PD, Tabares Saez H, Tabares Neyra H, Materno Parra Y, Pancorbo Sandoval E, Urbay Ceballos F, Acosta Marrero L, Osvaldo Gutierrez M, Jerez Labrada J, Miclau T. Management of Open Tibial Fractures in Cuba. *Rev Cuba de Ortop y Traumatol*. 2021;35(2):1-21.

- Holler JT, MacKechnie MC, Albright PD, Morshed S, Shearer DW, Terry MJ. The Impact of Inadequate Soft-Tissue Coverage Following Severe Open Tibia Fractures in Tanzania. *Plast Reconstr Surg Glob Open*. 2020;8(12):e3272-80.

- Roberts HJ, Albright PD, Shearer DW, Won N, MacKechnie MC, Coughlin RR, Miclau T, Morshed S, Sabharwal S. Motivations and Impact of International Rotations in Low- and Middle-Income Countries for Orthopaedic Surgery Residents: Are We on the Same Page? *Am J Surg*. 2021;221(2):245-53.

- Albright PD, MacKechnie MC, Roberts HJ, Shearer DW, Padilla L, Segovia J, Quintero JE, Amadei R, Baldy dos Reis F, Miclau T, and ACTUAR Open Tibia Study Group. Open Tibial Shaft Fractures: Treatment Patterns in Latin America. *J Bone Joint Surg Am*. 2020; 102(22):e126-36.

- Demetri L, Donnelley CA, MacKechnie MC, Toogood P. Comparison of Case-Based Learning and Traditional Lectures in an Orthopaedic Residency Anatomy Course. *J Surgical Educ*. 2020;78(2):679-85.

- MacKechnie MC, Nadeau M, Deering E, Thaller J, MacKechnie MA. Orthopaedic Walk-In Clinics: A Model to Lessen the Burden on Emergency Departments during the COVID-19 Pandemic. *J Orthop*. 2020;20:293-6.

- Pouramin P, Li CS, Busse JW, Sprague S, Devereaux PJ, Jagnoor J, Ivers R, Bhandari M, INORMUS Investigators. Delays in Hospital Admissions in Patients with Fractures Across 18 Low-Income and Middle-Income Countries (INORMUS): A Prospective Observational Study. *Lancet Glob Health*. 2020;8(5):e711-20.

- Padilla Rojas LG, Quintero S, Jiménez Avila JM, López Cervantes RE, Amadei Enghelmayer R, Pesciallo C, Garabano G, Kojima K, MacKechnie MC, Quintero JE. Hip Fracture Care: Latin America. *OTA Int*. 2020;3(1):e64-69.

- Albright PD, MacKechnie MC, Jackson JH, Chopra AM, Holler J, Flores Biard A, Padilla Rojas LG, Morshed S, Miclau T, Shearer DW, Terry MJ. Knowledge Deficits and Barriers to Performing Soft-Tissue Coverage Procedures: An Analysis of Participants in an Orthopaedic Surgical Skills Training Course in México. *OTA Int*. 2019;2(4):e44-49.

- Panthea P, Li CS, Sprague S, Busse JW, Bhandari M, INORMUS Investigators. A Multi-Center Observational Study on the Distribution of Orthopaedic Fracture Types Across 17 Low-and Middle-Income Countries. *OTA Int*. 2019;2(3):e26-36.

- Miclau T, MacKechnie MC, Shearer DW. Consortium of Orthopaedic Academic Traumatologists: A Model for Collaboration in Orthopaedic Surgery. *J Orthop Trauma*. 2018;32(7): S3-S7.

- Miclau T, MacKechnie MC, Shearer DW. Asociación de Cirujanos Traumatólogos de las Américas: Development of a Latin American Research Consortium. *J Orthop Trauma*. 2018; 32(7): S8-S11.

- Sprague S, McKay P, Chuan SL, Ivers R, Moroz P, Jagnoor J, Bhandari M, Miclau T, INORMUS Investigators. International Orthopaedic Multicenter Study in Fracture Care: Coordinating a Large-Scale Multicenter Global Prospective Cohort Study. *J Orthop Trauma*. 2018; 32(7): S58-S63.

- Chomsky- Higgins, Miclau TA, MacKechnie MC, et al. Barriers to Clinical Research in Latin America. *Public Health Front*. 2017; 5(57).

Accepted and Forthcoming

- MacKechnie MC, Miclau E, MacKechnie MA, Miclau T. Leadership Development Training for Orthopaedic Trauma Surgeons: An International Survey. *OTA Int*. 2023.

Contributing Authors

Dino Aguilar
Hospital Vivian Pellas, Managua, Nicaragua

Patrick D. Albright
Western Michigan University School of Medicine, Minneapolis, MN, USA

Rafael Amadei
Hospital Interzonal General de Agudos, San Martín de la Plata, La Plata, Buenos Aires, Argentina

Jorge Rubio Avila
Clinical Medica Sur, Guadalajara, Mexico

Fernando Baldy dos Reis
Federal University of Sao Paulo, Sao Paulo, Brazil

Roberto Balmaseda
Department of Orthopaedic Surgery, Centro de Investigaciones Médico-Quirúricas (CIMEQ), La Habana, Cuba

Antonio Barquet
Department of Traumatology and Orthopaedics, AEPSM, Montevideo, Uruguay

Brian P. Bernstein
Division of Orthopaedic Surgery, University of Cape Town, Cape Town, South Africa

Mohit Bhandari
Division of Orthopaedic Surgery, McMaster University, Hamilton, ON, Canada

Fernando Bidolegui
Servicio de Ortopedia y Traumatología, Hospital Sirio Libanes, Campana 4658, C1419, Buenos Aires, Argentina

Kelsey E. Brown
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Fernando de la Huerta
Unidad de Ortopedia y Traumatología, Guadalajara, México

Alfredo Ceballos
Department of Orthopaedic Surgery, Centro de Investigaciones Médico-Quirúricas (CIMEQ), La Habana, Cuba

Kathryn Chomsky-Higgins
San Francisco - East Bay Surgery Program, University of California, Oakland, CA, USA

Aman Chopra
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Fernando Contreras
Hospital San Juan de Dios, San José, Costa Rica

Bibiana Dello Russo
National Hospital of Pediatrics, Professor J.P Garrahan (Hospital Nacional de Pediatria, Profesor J.P. Garrahan), Buenos Aires, Argentina

Anthony Ding
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Igor Escalante
Hospital Universitario de Caracas, Caracas, Venezuela

Nelson Elias
Vila Velha Hospital, Espírito-Santo, Brazil

Michael J. Flores
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Antonio Flores Biard
Hospital Ángeles del Carmen, Guadalajara, Mexico

Sheryl L. Fuehrer
University of North Carolina at Chapel Hill, School of Medicine, Chapel Hill, NC, USA

Germán Garabano
Hospital Británico, Perdriel 74, C1280, Buenos Aires, Argentina

Mario Garuz
Hospital Santo Tomás, Calle 37 Este, Panama City, Panamá

Vincenzo Giordano
Orthopaedics and Traumatology Service, Professor Nova Monteiro, Municipal Hospital Miguel Couto, Leblon, Rio de Janeiro, Brazil

Jose M. Gómez
Sanatorio San Francisco de Asis, Guadalajara, México

Simon M. Graham
Oxford Trauma and Emergency Care, Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, United Kingdom;
Liverpool Orthopaedic and Trauma Service, Liverpool University Teaching Hospital Trust, Liverpool, United Kingdom

Enrique Guerado
Department of Orthopaedic Surgery, Traumatology, and Rehabilitation, University of Málaga, Hospital Costa del Sol, Marbella, Málaga, Spain

Jordan Holler
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Tobias Huttl
AO Education Institute, Zurich, Switzerland

Sergio Iriarte Vincenti
Hospital San Gabriel and Clinica del Sur, La Paz, Bolivia

J. Hunter Jackson
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Kodi Kojima
Universidade de Sao Paulo, Sao Paulo, Brazil

Nicolas Lee
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Leonardo Lopez Almejo
Federación Mexicana de Colegios de Ortopedia y Traumatología, A.C. Aguascalientes, México

Christian Lozano
Clínica Anglo Americana, Lima, Peru

Ricardo Madrigal
Servicios Médicos Municipales Cruz Verde, Guadalajara, Mexico

Michael A. MacKechnie
Department of Orthopaedic Surgery, Cleveland Clinic Martin Health, Stuart, Florida

Claude Martin
AO Alliance Foundation, Davos, Switzerland

Fryda Medina
Hospital de Traumatología Instituto Mexicano del Seguro Social, Mexico City, Mexico

Gavino Merchan
Hospital de la Policia Nacional, Guayaquil, Ecuador

Theodore Miclau III
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Theodore A. Miclau
Stanford University, Palo Alto, CA, USA

Saam Morshed
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Jamieson M. O'Marr
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Luis G. Padilla Rojas
Puerta de Hierro Hospital, Zapopan, Jalisco, México

Sebastian Pereira
Servicio de Ortopedia y Traumatología, Hospital Sirio Libanes, Campana 4658, C1419, Buenos Aires, Argentina

Rodrigo Pesantez
Fundación Santa Fe de Bogotá, Universidad de los Andes, Department of Orthopedic Surgery, Bogotá, Colombia

Cesar A. Pesciallo
Hospital Británico, Perdriel 74, C1280, Buenos Aires, Argentina

Jose E. Quintero
Hospital Universitario San Jorge, Clínica de Ortopedia y Traumatología, Pereira-Risaralda, Colombia

Sergio Quintero Hernandez
Universidad de Guadalajara, Guadalajara, México

Marcelo W. Rio
Ortopedia y Traumatología Clínica Zabala, Buenos Aires, Argentina

Heather J. Roberts

Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Carlos Sánchez Valenciano
Centro Medico de Caracas, Caracas, Venezuela

Mariana Salazar
Hospital Central "Dr. Ignacio Morones Prieto", Monterrey, Mexico

Michael Schuetz
Queensland University of Technology, Herston, Queensland, Australia

Julio Segovia Altieri
Instituto de Prevision Social, Servicio de Ortopedia y Traumatologia, Asunción, Paraguay

David W. Shearer
Department of Orthopaedic Surgery, Institute for Global Orthopaedics and Traumatology, Orthopaedic Trauma Institute, University of California, San Francisco, CA, USA

Horacio Tabares Neyra
Department of Orthopaedic Surgery, Centro de Investigaciones Médico-Quirúricas (CIMEQ), La Habana, Cuba

Michael J. Terry
Division of Plastic and Reconstructive Surgery, Institute for Global Orthopaedics and Traumatology, Zuckerberg San Francisco General Hospital, San Francisco, CA, USA

Esther M.M. Van Lieshout
Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center, Rotterdam, The Netherlands

Maura Vega Ocampo
Hospital General, Regional Número 20, Tijuana BC, México

Michael H.J. Verhofstad
Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center, Rotterdam, The Netherlands

Eduardo Vilensky
Casmu, Spanish Association, General Bulevar Artigas (Asociación Española, Bulevar General Artigas), Montevideo, Uruguay

PhD Portfolio

Summary of PhD training and teaching

Name PhD student: Madeline C. MacKechnie Erasmus MC Department: Trauma Research Unit, Department of Surgery	PhD period: November 2020 – November 2023 Promotor(s): Prof. Dr. M.H.J. Verhofstad Supervisors: Dr. E.M.M. Van Lieshout and Dr. Theodore Miclau

1. PhD training

	Year	Workload (Hours/ECTS)
General courses (scientific integrity, biostatistics, scientific writing, etc.)		
- UCSF Statistical Computing in Clinical Research Course	2020	1.0
- Quality Improvement through SOP Development and Implementation Course – Society of Clinical Research Associates (SOCRA)	2020	1.0
- Principles of Clinical Research Course – Orthopaedic Research Society (ORS)	2023	0.4
- Good Clinical Practice	2023	0.2
- Orthopaedic trauma webinar series *Open Fracture and Soft-Tissue Reconstruction* *Pelvic and Acetabular Fractures* *Advanced Flaps* *Limb Deformity Correction* *Pelvic Ring Injuries* *Tibial Plateau Fractures* *Ankle Fractures* *Pediatric Femur Fractures* *Tibial Plafond Fractures*	2022	1.0
- Good Clinical Practice	2020-2023	1.0
- Professional Grant Writing Workshop	2020	0.2
- Biomedical Responsible Conduct of Research Course	2020	0.2
Presentations		
- ACTUAR Hip Fracture Care in Latin America – OTA	2023	0.5
- Predictors of Musculoskeletal Clinical Care – OTA	2023	0.5
- Establishing Consensus on Essential Resources for Musculoskeletal Care: A Modified Delphi Study – IOTA	2022 2022	0.5 0.5
- Management of Soft-Tissue in Latin America: Techniques, Timing, and Resources – OTA	2022 2022	0.5 0.5
- Management of Open Tibia Fractures in Cuba – OTA		

- Reoperation Rates Following Open Tibia Fracture Treatment in Argentina – OTA	2022	0.5
- Global Leadership Development for Orthopaedic Trauma Surgeons: Assessment of Leadership Course Needs and Barriers – OTA	2021	0.2
- Orthopaedic Walk-In Clinics (OWICs) During the COVID-19 Pandemic: Nonemergent Patient Referrals During and After Mandatory Stay-At-Home-Legislation (MSHL) – AAOS	2020	0.2
- International Clinical Research and Surgical Education Opportunities in Orthopaedic Trauma	2020	0.2
- Junior Academy – UCSF Orthopaedic Surgical Training Facility IGOT Presentation		
(Inter)national conferences		
- San Francisco International Trauma Course	2023	1.0
- San Francisco International Trauma Course	2022	1.0
- San Francisco International Trauma Course	2021	1.0
- San Francisco International Trauma Course	2020	1.0
- Orthopaedic Trauma Association (OTA)	2023	1.0
- Orthopaedic Trauma Association (OTA)	2022	1.0
- American Academy of Orthopaedic Surgeons (AAOS)	2023	1.0
- American Academy of Orthopaedic Surgeons (AAOS)	2022	1.0
- American Academy of Orthopaedic Surgeons (AAOS)	2021	1.0
- International Orthopaedic Trauma Association (IOTA)	2022	1.5
- International Combined Orthopaedic Research (ICORS) World Congress of Orthopaedic Research	2022	1.0
- AO Trauma Scientific Conference (Davos, Switzerland)	2022	1.0
- Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT)	2021	1.0
- Federación Mexicana de Colegios de Ortopedia y Traumatología (FEMECOT)	2020	1.0
- Sociedad Colombiana de Cirugía Ortopédica y Traumatología (SCCOT)	2021	1.0
- Sociedad Cubana de Ortopedia y Traumatología (SCOT)	2021	1.0
- Asociación Argentina de Traumatología y Ortopedia (AATO)	2021	1.0
Other (Career support)		
- Peer Reviewer for Medical Research Council Clinician Scientist Fellowship	2023	0.2
- Peer Reviewer for BMJ Open	2021	0.2
	2020	0.2

- Peer Reviewer for Journal of Health Planning and Management		
- UCSF School of Medicine Leadership Development Program	2020	3.0
- Trainee International Initiatives (TII) Global Health Committee	2020-2023	1.0

2. Teaching

	Year	**Workload (Hours/ECTS)**
- Tanzania Surgical Management and Reconstructive Training (SMART) Course	2023	1.0
- Cuba Surgical Management and Reconstructive Training (SMART) Course	2022	1.0
- San Francisco Surgical Management and Reconstructive Training (SMART) Course	2022	1.0
- San Francisco Surgical Management and Reconstructive Training (SMART) Course	2021	1.0
- Prospective Observational Open Tibia Fracture Management Multi-Center Study Enrollment Training	2021	1.0
- Mexico Surgical Management and Reconstructive Training (SMART) Course	2020	1.0
TOTAL		**37.2**

Acknowledgements

My interest in Latin American health systems first originated during my undergraduate studies but developed and changed with time. Working at the Orthopaedic Trauma Institute at the University of California, San Francisco (UCSF) has been especially important to my academic approach and inspired me to think about my interests through an orthopaedic lens.

I want to thank my three doctoral supervisors for their guidance and support. This thesis could not have been possible without my UCSF colleague and supervisor, Dr. Theodore Miclau. I am grateful for Dr. Miclau's belief in this project, support of this work from early vision to final execution, leadership role in establishing ACTUAR, and for our shared appreciation of all things Latin! Thank you very much to Dr. Michael Verhofstad for his invaluable academic support, sage advice, and willingness to oversee this PhD from abroad. Last but not least, I would like to express my sincere gratitude to Dr. Esther Van Lieshout for her insight and expertise on clinical research in trauma care, input on the studies presented in this thesis, and hands-on administrative direction.

The research for this dissertation could not have been conducted without the team efforts and insights of the ACTUAR collaborators. Since its inception five years ago, ACTUAR has published over 20 articles, with many additional projects underway. I am also appreciative that this organization has blossomed from a community of colleagues into a circle of friends.

Finally, I am grateful for my family, and particularly my sister and mother, who have set excellent examples for me.

Curriculum Vitae

Madeline Camilla MacKechnie was born in Seattle, WA, United States of America. She graduated *summa cum laude* with a Bachelor's degree (Honors) in International Development Studies and a Master's degree in Global Development Studies from Queen's University in Kingston, ON, Canada. Her work focused on equitable solutions to healthcare disparities, specifically in Latin America. Madeline's interest in the intersection between global health and orthopaedics was sparked while working as a Spanish/English translator on an orthopaedic mission trip in Quito, Ecuador. Madeline is the Director of Global Programs for the Institute of Global Orthopaedics and Traumatology (IGOT), an academic global orthopaedic organization, based within the Orthopaedic Trauma Institute (OTI) in the Department of Orthopaedic Surgery at the University of California, San Francisco (UCSF). Alongside UCSF faculty member, Dr. Theodore Miclau, Madeline has helped develop the Asociación de Cirujanos Traumatólogos de las Américas (ACTUAR), a collaborative initiative focused on building research capacity in Latin America, as well as the Consortium of Orthopaedic Academic Traumatologists (COACT), an organization representing leading orthopaedic institutions across North America that promotes global health efforts and best practices in musculoskeletal trauma care.