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Impact of Surgical Training on Incidence of Surgical Site Infection

Rachel Rosenthal · Walter P. Weber · Marcel Zwahlen · Heidi Misteli · Stefan Reck · Daniel Oertli · Andreas F. Widmer · Walter R. Marti

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Abstract

Background Despite availability of other training forms, tutorial assistance cannot be entirely replaced in surgical education. Concerns exist that tutorial assistance may lead to an increased rate of surgical site infection (SSI). The purpose of the present study was to investigate whether the risk of SSI is higher after surgery with tutorial assistance than after surgery performed autonomously by a fully trained surgeon.

Methods All consecutive visceral, vascular, and traumatological inpatient procedures at a Swiss University Hospital were prospectively recorded during a 24-month period, and the patients were followed for 12 months to ascertain the occurrence of SSI. Using univariable and multivariable logistic regressions, we assessed the association of tutorial assistance surgery with SSI in 6,103 interventions.

Results Autonomously performed surgery was associated with SSI in univariable analysis (5.36% SSI vs. 3.81% for tutorial assistance, $p = 0.006$). In multivariable analysis, the odds of SSI for tutorial assistance was no longer significantly lower (Odds Ratio [OR] = 0.82; 95% Confidence Interval [CI]: 0.62–1.09; $p = 0.163$).

Conclusions Surgical training does not lead to higher SSI rate if trainees are adequately supervised and interventions are carefully selected. Although other forms of training are useful, tutorial assistance in the operating room continues to be the mainstay of surgical education.

Introduction

Traditionally, surgical skills are acquired primarily in the operating room, first by observing and then by taking an increasingly active role in the procedure, pursuant to William Halsted's apprenticeship model ("see one, do one, teach one") [1]. The use of animal models is criticized by animal-rights organizations. Ethical, economic, and educational considerations have recently led to the development of alternative methods for teaching surgical techniques, such as box model or virtual reality (VR) simulation [2]. Virtual reality appears to be an ideal tool for training physicians in laparoscopic surgical skills. The interface between trainee and surgical site consisting of a video screen and instruments can readily be simulated by modern VR simulation technology. One major advantage of the VR simulator lies in its ability to serve not only as a training tool but also as a precise and objective assessment tool. Nevertheless, tutorial assistance during actual surgery continues to be necessary if the trainee is to acquire full command of surgical skills. This training system can only be justified, however, if it involves no rise in the complication rate. Because one of the most common postoperative complications is surgical site infection (SSI), the SSI rate is used here as one possible indicator

R. Rosenthal · W. P. Weber · H. Misteli · S. Reck · D. Oertli · W. R. Marti (✉)
Department of Surgery, Basel University Hospital, 4031, Basel, Switzerland
e-mail: wrmarti@uhbs.ch

A. F. Widmer
Division of Infectious Diseases and Hospital Epidemiology, Basel University Hospital, 4031, Basel, Switzerland

M. Zwahlen
Research Support Unit, Institute of Social and Preventive Medicine, University of Bern, Hochschulstrasse 4, 3012, Bern, Switzerland

of the overall complication rate associated with surgical training.

The purpose of the present study was to investigate the hypothesis that tutorial training in the operating room does not lead to a higher incidence of SSI than that recorded in surgery performed autonomously by board-certified surgeons.

Materials and methods

Patients

The incidence of SSI in all the visceral, vascular, and traumatological operations performed between 1 January 2000 and 31 December 2001 on inpatients at Basel University Hospital, Switzerland, was prospectively recorded. Outpatient surgery was excluded.

Surgery

An associate professor or senior board-certified fellow determined which procedures would be conducted under tutorial assistance in accordance with the following criteria: the assessment of patient comorbidity, the complexity of the intervention, and the trainee's operating experience. Complex interventions and surgery involving polymorbid patients were performed by a senior fellow, an associate professor, or the department head.

Operations were classified into one of two groups: tutorial assistance or autonomous interventions performed by a board-certified surgeon. Tutorial assistance was defined to be surgery performed by a resident assisted by a board-certified surgeon, or operations conducted by a general surgery fellow, supervised by a board-certified surgeon with extensive expertise in a field in which the lead surgeon was less experienced; an example of the latter might be a board-certified surgeon performing a vascular intervention assisted by a board-certified vascular surgeon.

The standard operation procedure in the operating room (OR) requires a three-step desinfection around the incision area before sterile drapes are placed on the patient. The standard for desinfection was Betaseptic (Mundipharma, Basel, Switzerland), a solution of 4% povidone-iodine (w/v) and 96% alcohol (w/v) (active ingredients: iodine 3,2 g as povidone-iodine, 389 g 2-propanol (49.5% v/v) and 389 g ethanol (46.2% v/v) per 100 ml); Braunoderm (Braun Medical, Melsungen, Gemany), a solution of 1% povidone-iodine (w/v) in 50% 2-propanol (w/v), and water (active ingredients: 0.9 g as povidone-iodine, 45.75 g 2-propanol (58.2% v/v) per 100 ml; further ingredients: sodium hydrogen phosphate dihydrate, potassium iodide, and purified water); and Braunol (Braun Medical, Melsungen, Gemany), a solution of 7.5% povidone-iodine (w/v) and water (active ingredient: 7.5 g povidone-iodine; further ingredients: sodium hydrogen phosphate dehydrate, sodium iodate, macrogol laurylether-9 EO, sodium hydroxide, and purified water).

In case of allergies, Octenisept—a European product not licensed in the United States, but with a spectrum of antimicrobial activity similar to that of chlorhexidine—was used. This practice follows the World Health Organization (WHO) guideline; one of the authors is part of the Task Force on Patient Safety in Surgery. The guideline is now published in part, and was officially presented in June 2008 in Washington, DC.

Routine antibiotic prophylaxis for elective and emergency surgery consisted of a 1.5-g single shot of cefuroxime for class II (clean-contaminated) and class III (contaminated) wounds [3–6], as well as for class I (clean) wounds where surgery entailed implanting a foreign body. A 500-mg dose of metronidazole was added in colorectal surgery. In procedures with a duration longer than 4 h, a second dose of these antibiotics was administered, pursuant to hospital guidelines. Doses were adapted for patients with impaired renal function. Antibiotic prophylaxis was extended for 24 h after the intervention in osteosynthesis patients, who received 0.75 g of cefuroxim after 8 and 16 h. In case of class I wounds without implanting a foreign body, no antibiotics were administered. Patients with class IV (dirty-infected) wounds were either treated with antibiotics in lieu of antimicrobial prophylaxis or, in the event of simple superficial abscess incisions, received no antibiotics at all.

Surgical site infection

Further to Centers for Disease Control and Prevention criteria [5, 6], surgical site infections occurring within 30 days of an operation involving no implant or within one year otherwise were prospectively recorded and classified as superficial incisional, deep incisional, or organ/space SSIs.

Data acquisition

Data on SSI risk factors were prospectively collected (Table 1). The lead anesthesiologist prospectively recorded the American Society of Anesthesiologists (ASA) classification, height, body weight, operating time, and the administration of antimicrobial prophylaxis, whereas the surgeon prospectively recorded wound classification. Immediately after surgery, surgeons were documented by name as the surgeon performing the operation, the first assistant (who was the senior surgeon in case of tutorial assistance), and the second assistant. Thus it was taken into

Table 1 Surgical procedures by presence of tutorial assistance and procedural characteristics

Variable	Tutorial assistance *n* (column percent)	Autonomous *n* (column percent)	*p* Value
Total	2,388 (100%)	3,715 (100%)	
Age			
<30	283 (11.9)	258 (6.9)	<.001
30–39	376 (15.7)	398 (10.7)	
40–49	346 (14.5)	545 (14.7)	
50–59	322 (13.5)	625 (16.8)	
60–69	309 (12.9)	722 (19.4)	
70–79	348 (14.6)	713 (19.2)	
80–89	321 (13.4)	385 (10.4)	
≥90	83 (3.5)	69 (1.9)	
Sex			
Female	1,101 (46.1)	1,854 (49.9)	.004
Male	1,287 (53.9)	1,861 (50.1)	
Department			
Visceral surgery	1,077 (45.1)	1,597 (43.0)	<.001
Traumatology	1,121 (46.9)	1,317 (35.4)	
Vascular surgery	190 (8.0)	801 (21.6)	
ASA			
I	382 (16.0)	464 (12.5)	<.001
II	1,181 (49.5)	1,661 (44.7)	
III	746 (31.2)	1,325 (35.7)	
IV or V	79 (3.3)	265 (7.1)	
BMI (kg/m^2)			
<18	66 (2.8)	124 (3.3)	<.001
<25	983 (41.2)	1,588 (42.8)	
<30	637 (26.7)	1,070 (28.8)	
≥30	290 (12.1)	438 (11.8)	
Missing	412 (17.2)	495 (13.3)	
Diabetes			
No	2,172 (90.9)	3,350 (90.2)	.311
Yes	216 (9.1)	365 (9.8)	
Immunosuppression			
No	2,324 (97.3)	3,547 (95.5)	<.001
Yes	57 (2.4)	161 (4.3)	
Missing	7 (0.3)	7 (0.2)	
Leukocytes (μl)			
<3,500	48 (2.0)	113 (3.0)	<.001
3,500–10,000	1,315 (55.1)	2,243 (60.4)	
≥10,000	849 (35.5)	1,135 (30.6)	
Missing	176 (7.4)	224 (6.0)	
Tobacco			
Never	1,239 (51.9)	1,991 (53.6)	.319
Previous/ongoing	1,032 (43.2)	1,533 (41.3)	
Missing	117 (4.9)	191 (5.1)	

Table 1 continued

Variable	Tutorial assistance *n* (column percent)	Autonomous *n* (column percent)	*p* Value
Antimicrobial prophylaxis			
Yes	1,722 (72.1)	2,774 (74.7)	.027
No	666 (27.9)	941 (25.3)	
Wound class			
Clean	1,398 (58.5)	2,307 (62.1)	<.001
Clean-contaminated	358 (15.0)	637 (17.1)	
Contaminated	313 (13.1)	422 (11.4)	
Dirty-infected	319 (13.4)	349 (9.4)	
T-time exceeded[a]			
Yes	425 (17.8)	775 (20.9)	.006
No	1,962 (82.1)	2,940 (79.1)	
Missing	1 (<0.1)	0 (0.0)	
Other pre-existing infections			
Yes	259 (10.9)	473 (12.7)	.027
No	2,129 (89.1)	23,242 (87.3)	
Insurance			
Private	147 (6.2)	1,684 (45.3)	<.001
Basic	2,241 (93.8)	2,030 (54.6)	
Missing	0 (0.0)	1 (< 0.1)	

ASA American Society of Anesthesiologists, *BMI* body mass index

[a] *T-time* 75th percentile time as defined in the NNIS system [7]

account who actually performed the surgery and not who was assigned to do so. Later, all interventions were earmarked for the "tutorial training" or "autonomously performed surgery" group by an associate professor who performed a detailed review of the expertise and training/experience of all surgical ward physicians. Residents prospectively screened all patients for any possible postoperative complications, including infectious processes such as SSI. They identified complications, documented treatment at discharge, and entered the information on a predesigned follow-up form. Each of these forms was cross-checked at the time of the patient's discharge by a consultant. All of the patients' charts were reviewed by a member of our study group to collect the information and to further screen for SSI that were not mentioned on the predesigned form. Suspected or known SSI patients then underwent full chart review by a board-certified infectious disease specialist. All the hospital stay data were entered on an electronically readable case report form (Cardiff TELEForm Desktop V 8.0, 2002, Verity Incorporated, Sunnyvale, CA), and the completed forms were cross-checked by a research team member.

In addition, patients were assessed for SSI after discharge. The first of the various assessment methods used was outpatient chart review: most of the patients operated on by the traumatology division were monitored clinically and radiologically as outpatients after discharge. The second was a questionnaire sent to patients' primary care physicians, who routinely monitored surgical wounds and removed sutures. When no reply was received, up to two reminders were mailed. Visiting research team nurses also offered primary care doctors assistance in completing the forms on the basis of their patient records. Finally, the 17% of the patients for whom no follow-up was available were surveyed by phone to complete the missing information. Where doubts arose respecting the quality of the information furnished by these patients, they were excluded. A different data sheet was used for the outpatient monitoring. Here also, all instances of SSI were validated by the hospital hygiene and epidemiology ward, which reviewed all the relevant records. Primary care physicians and/or patients were contacted for additional information during the validation process wherever necessary. The inpatient and outpatient monitoring forms were then scanned and the data cleaned for mismatches and exported to an Excel file (Windows Microsoft Excel 2003, Microsoft Corporation, Redmond, WA).

Statistical analysis

In descriptive analyses we described categorical variables by providing frequency and percentages. To compare categorical characteristics between procedures with and without SSI we calculated the chi square statistics and the corresponding p value for the null hypothesis of no association. The same procedure was followed for the univariable comparison of surgeries with and without tutorial assistance. All p values were two-sided, and statistical significance was defined as $p < 0.05$.

Multivariable logistic regression models were fitted to the data to take account of potentially confounding factors, while odds ratios and 95% confidence intervals were used to describe the relationship between the odds of contracting an SSI and the characteristics included in the analysis. For characteristics with several possible values, such as the ASA score, indicator variables were constructed for each separate value and entered in the models, omitting the indicator variable for the control group.

In an additional sensitivity analysis we matched procedures with an SSI to procedures without an SSI for the same type of surgical intervention, same ASA score and same wound class. In this matched case-control set we then performed an analysis using conditional logistic regression which accounts for the matching.

All the variables listed in Table 1 except surgeon experience were included in this analysis. Stata software (Stata Statistical Software: Release 9.2; Stata Corporation, College Station, TX) was used to analyze the data.

Results

General characteristics

Of the 6,540 interventions performed between 1 January 2000 and 31 December 2001, in-hospital data were not available for 257 interventions. Because the information on the surgeon's experience was insufficient and/or there was no record of whether surgery had been performed autonomously or with tutorial assistance, another 180 interventions also had to be excluded. Therefore, 6,103 (93.3%) interventions were analyzed.

A long-term follow-up data set was built for 5,557 of the 6,103 interventions (91.1%). In 83.3% (4,629/5,557) cases, follow-up was performed by a physician, whereas in 16.7% (928/5,557) of the cases, patients were contacted directly by telephone.

The overall mortality rate for the 6,103 interventions was 3.7% ($n = 225$). In 52% of the interventions ($n = 3{,}148$) patients were male; in 48% ($n = 2{,}955$), female. Mean patient age was 57 years (±19.4; range 7–103 years). In 14% ($n = 846$) of the procedures the patients' ASA score was I; in 46% ($n = 2{,}842$), ASA II; in 34% ($n = 2{,}071$), ASA III; and in 6% ($n = 344$), ASA IV or V. Antimicrobial prophylaxis was administered to 4,496 (74%) patients. Overall, 61% ($n = 3{,}705$) of the wounds were class I; 16% ($n = 995$), class II; 12% ($n = 735$), class III; and 11% ($n = 668$), class IV.

Of the 6,103 interventions, 2,229 (36.5%) were performed by residents; 2,290 (37.5%), by fellows; and 1,584 (26.0%), by an associate professor or the department head. Surgery was performed with tutorial assistance in 39.1% of the cases ($n = 2{,}388$) and autonomously in 60.9% ($n = 3{,}715$). Table 1 gives an overview of the variables studied, and Table 2 lists the types of interventions performed and the breakdown between tutorial assistance and autonomously performed surgery.

Surgical site infections

The overall rate of SSI was 4.75% ($n = 290$). Of these 290 SSI, 29.7% ($n = 86$) were recorded as superficial; 29.7% ($n = 86$), as deep; and 40.6% ($n = 118$), as organ/space. The median hospital stay was 9 days (with an interquartile range of 5-16 days). Of the SSI recorded, 64% ($n = 186$) were diagnosed during the period of hospitalization and 36% ($n = 104$) developed after discharge.

Table 3 gives an overview of the SSI rate for the variables analyzed. Univariable analysis identified the following variables associated with an increased odds of SSI: age, vascular procedure, ASA classification, diabetes, high preoperative leukocyte count, past or present smoking, wound classification, pre-existing infections other than

Table 2 Interventions performed: breakdown by tutorial assistance and autonomous surgery

Intervention	Tutorial assistance *n* (row percent)	Autonomous *n* (row percent)
Total	2,388 (39.13%)	3,715 (60.87%)
Visceral surgery		
Upper GI	36 (26.5)	100 (73.5)
Lower GI	225 (38.9)	354 (61.1)
Proctology	70 (48.6)	74 (51.4)
Hepatobiliary and pancreatic	137 (46.0)	161 (54.0)
Endocrine	46 (19.9)	185 (80.1)
Hernia repair	248 (58.2)	178 (41.8)
Others	134 (23.3)	441 (76.7)
Vascular surgery		
Aorta or carotids	14 (13.9)	87 (86.1)
Peripheral arterial	55 (14.7)	320 (85.3)
Venous, shunts, ports	62 (20.3)	244 (79.7)
Traumatology		
Osteosynthesis	604 (49.2)	623 (50.8)
Prosthesis	77 (54.6)	64 (45.4)
Soft tissue interventions	444 (54.5)	370 (45.5)
Others	236 (31.5)	514 (68.5)

SSI, and exceeded T-time (operation time in excess of the 75th percentile of duration of type-specific surgery) [7].

Multivariable analysis identified the following risk factors ($p < 0.05$): age 80–89 years ($p = 0.029$), body mass index (BMI) ≥ 30 kg/m^2 ($p = 0.018$), past or present smoking ($p = 0.033$), contaminated wounds ($p < 0.001$) and clean-contaminated ($p = 0.003$) wounds, pre-existing infections other than SSI ($p = 0.009$), and exceeded T-time ($p < 0.001$) (Table 4, overall variable *p* values). Contrary to the univariable analysis findings, in multivariable analysis vascular procedure, ASA classification, diabetes, and high preoperative leukocyte count were not identified as significant risk factors.

Teaching assistance versus autonomously performed interventions

The SSI rate for the 3,715 interventions autonomously performed by board-certified surgeons was 5.36% ($n = 199$). In the tutorial assistance group, with 2,388 interventions, the SSI rate was only 3.81% ($n = 91$). In univariable analysis this difference was significant ($p = 0.006$, OR = 0.70, 95% CI = 0.543–0.902), but multivariable analyses failed to show any significant difference in the SSI rate between tutorial assistance, (*p* value = 0.163; OR = 0.82; 95% CI = 0.62–1.09) and

Table 3 Univariable analysis: number of surgical procedures, number and percentage of surgical site infections (SSI) by variable

Variable	Number of surgical procedures	Number of SSI	% SSI	*p* Value (univariable analysis)
Total	6,103	290	4.75	–
Age (years)				
<30	541	15	2.77	0.023
30–39	774	23	2.97	
40–49	891	38	4.26	
50–59	947	48	5.07	
60–69	1,031	57	5.53	
70–79	1,061	58	5.47	
80–89	706	43	6.09	
≥90	152	8	5.26	
Sex				
Female	2,955	138	4.67	0.771
Male	3,148	152	4.83	
Department				
Visceral surgery	2,,674	145	5.42	<0.001
Traumatology	2,438	80	3.28	
Vascular surgery	991	65	6.56	
ASA score				
I	846	20	2.36	<0.001
II	2,842	108	3.80	
III	2,071	131	6.33	
IV or V	344	31	9.01	
BMI (kg/m^2)				
<18	190	10	5.26	0.059
<25	2,571	106	4.12	
<30	1,707	85	4.98	
≥30	728	49	6.73	
Missing	907	40	4.41	
Diabetes				
No	5,522	250	4.53	0.011
Yes	581	40	6.88	
Immunosuppression				
No	5,871	273	4.65	0.071
Yes	218	17	7.80	
Missing	14	0	0	
Leukocytes (µl)				
<3,500	161	4	2.48	0.001
3,500–10,000	3,558	160	4.50	
≥10,000	1,984	119	6.00	
Missing	400	7	1.75	
Tobacco				
Never	3,230	135	4.18	0.024
Previous/ongoing	2,565	144	5.61	
Missing	308	11	3.57	

Table 3 continued

Variable	Number of surgical procedures	Number of SSI	% SSI	*p* Value (univariable analysis)
Antimicrobial prophylaxis				
Yes	4,496	222	4.94	0.253
No	1,607	68	4.23	
Wound class				
Clean	3,705	126	3.40	<0.001
Clean-contaminated	995	66	6.63	
Contaminated	735	61	8.30	
Dirty-infected	668	37	5.54	
T-time exceeded[a]				
Yes	1,200	98	8.17	<0.001
No	4,902	192	3.92	
Missing	1	0	0	
Other pre-existing infections				
Yes	732	62	8.47	< 0.001
No	5,371	228	4.25	
Insurance				
Private	1,831	86	4.70	0.967
Basic	4,271	204	4.78	
Missing	1	0	0	
Surgeon				
Resident	2,229	71	3.19	<0.001
Fellow	2,290	132	5.76	
Associate prof./head department	1,584	87	5.49	
Tutorial assistance				
Yes	2,388	91	3.81	0.006
No	3,715	199	5.36	

[a] *T-time* 75th percentile time as defined in the NNIS system [7]

autonomously performed interventions (Table 4, Fig. 1). Multivariable analysis was supplemented by including the 14 different anatomical areas of interventions listed in Table 2 as additional variables. The results found with this analysis were similar to the above, with a *p* value of 0.170, an OR = 0.82, and a 95% CI = 0.61–1.09. Furthermore, we assessed whether there is evidence for differences in this association across departments by incorporating effect modification terms into the multivariable logistic regression model and tested for effect modification, calculating the likelihood ratio test. We found no evidence for effect modification ($p = 0.19$).

We obtained very similar results in our sensitivity analysis using the approach of matching cases to controls and to perform an analysis using conditional logistic regression. We obtained an odds ratio of 0.85 for the

Table 4 Multivariable analysis: odds-ratio and 95% confidence intervals for the association of surgical site infection (SSI) by variable

Variable category	Odds ratio	95% Confidence interval	*p* Value
Age			
<30	Reference group		0.199
30–39	1.00	0.51–2.0	
40–49	1.38	0.74–2.6	
50–59	1.64	0.88–3.0	
60–69	1.57	0.85–2.9	
70–79	1.44	0.77–2. 7	
80–89	2.07	1.08–4.0	
≥90	2.34	0.92–6.0	
Sex			
Female	1.04	0.80–1.34	.781
Male	Reference group		
Department			
Visceral	Reference group		0.081
Traumatology	0.77	0.57–1.05	
Vascular	1.18	0.83–1.66	
ASA score			
I	Reference group		0.321
II	1.033	0.62–1.72	
III	1.28	0.75–2.2	
IV or V	1.55	0.80–3.0	
BMI (kg/m^2)			
18–25	Reference group		0.121
<18	0.99	0.50–2.0	
>25	1.20	0.89–1.62	
≥30	1.56	1.08–2.2	
Diabetes			
Yes	1.06	0.73–1.54	.778
No	Reference group		
Immunosuppression			
Yes	1.38	0.81–2.3	.237
No	Reference group		
Leukocytes (µl)			
3,500–10,000	Reference group		0.100
<3,500	0.51	0.18–1.40	
>10,000	1.22	0.94–1.59	
Tobacco			
Yes	1.34	1.03–1.75	.033
No	Reference group		

Table 4 continued

Variable category	Odds ratio	95% Confidence interval	p Value
Antimicrobial prophylaxis			
No	0.85	0.63–1.15	.295
Yes	Reference group		
Wound class			
Clean	Reference group		<0.001
Clean-contaminated	1.66	1.19–2.3	
Contaminated	2.20	1.55–3.1	
Dirty-infected	1.53	0.99–2.3	
T-time exceeded[a]			
Yes	2.00	1.53–2.6	<.001
No	Reference group		
Other pre-existing infections			
Yes	1.53	1.112–2.104	.009
No	Reference group		
Insurance			
Private	1.02	0.76–1.36	.912
Basic	Reference group		
Tutorial assistance			
Tutorial	0.82	0.62–1.09	.163
Autonomous	1.0		

Results were derived from a multivariable logistic regression model that included all of the listed variables and duration of surgery in minutes

The number of surgical procedures as well as the number and percentage of surgical site infections (SSI) per variable are given in Table 3

[a] *T-time* 75th percentile time as defined in the NNIS system [7]

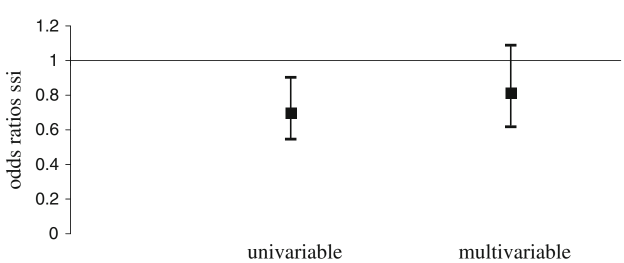

Fig. 1 Odds ratio for SSI in surgery involving tutorial assistance compared to surgery performed autonomously (control group) in univariable ($p = 0.006$) and multivariable analysis ($p = 0.163$)

association of tutorial assistance (versus autonomously performed interventions) with SSI (95% CI = 0.61–1.18; p value = 0.328).

Discussion

Today, surgical training can be delivered by a number of techniques, including box-models and virtual reality simulation [2, 8–11]. Nevertheless, these training methods, which must be viewed as supplements to the traditional apprenticeship model, cannot replace tutorial assistance in the operating room. Even so, concerns have been raised about the possible impact of tutorial assistance on the rate of complications such as SSI, which would be detrimental to patients. This study clearly shows that teaching assistance does not necessarily lead to high SSI rates if supervision is guaranteed and the selection of patients is in keeping with the surgical trainee's expertise.

One of the most common postoperative complications is SSI. A survey conducted in four university hospitals in Switzerland found SSI to be the most frequent nosocomial infection after surgery [12]. The risk factors for contracting SSI, of which there are many, may be patient-related or surgery-related [5, 13]. Among the patient-related factors are age, nutritional status, obesity, diabetes mellitus, tobacco abuse, and immunosuppression, whereas preoperative surgical scrub, duration of operation, administration and timing of antibiotic prophylaxis [14], implantation of foreign material, surgical drains and surgical techniques, including asepsis, hemostasis, atraumatic technique and obliteration of dead spaces, constitute surgery-related risk factors. The Centers for Disease Control and Prevention (CDC) NNIS Web site regularly publishes multicenter data on SSI rates [15]. The pooled mean SSI rates by operative procedure and risk index category published in its latest report, which covers the period running from January 1992 through June 2004, ranged from 0.15% (other endocrine system, risk index category 0) to 11.25% (colon, risk index category 3) [16]. For herniorrhaphy for instance, the pooled mean SSI rate was 0.81% for risk index category 0 [16]. A 10-year wound infection surveillance program conducted prior to this period found SSI rates to be 2.5% overall, 1.4% for class I (63.3%), 5.4% for class II (26.4%), and 8.4% for class III (10.3%) wounds [17]. In the present study, the overall SSI rate was higher. This may be explained by the different factors considered in our study. For example, Olson et al. [17] took into account only the first 30 postoperative days in their assessment of SSI. According to the CDC definition however, SSI should be considered as a complication occurring up to one year of an operation involving an implant. Importantly, the report by Olsen et al. did not include class IV wounds but involved more class I and class II wounds, accounting for a lower overall SSI rate. Moreover, our data acquisition is a combination of prospective data entry, retrospective chart review, and peer review by the hospital epidemiology staff. The combination of active surveillance by two independent departments, complemented by vigorous postdischarge surveillance, explains the higher infection rates. In addition, a tertiary care center in general has higher infection rates due to the case-mix that is very difficult to control for by statistical methods. Therefore we strongly believe that our SSI identification rate is as complete as possible, resulting in an incidence higher than those reported by other authors.

According to the data collected for the present survey, a high proportion (36%) of SSI were diagnosed after discharge. Therefore, follow-up for surgical patients and post-discharge SSI monitoring are crucial [18].

Over 25 years ago, a negative correlation was shown to exist between a surgeon's case volume and the respective SSI rate after appendectomy, herniorrhaphy, cholecystectomy, colon resection, and abdominal hysterectomy [19]. This same indirect relationship has recently been found for coronary artery bypass graft surgery [20].

Nonetheless, very few studies, and all with widely varying designs, have been conducted on the effect of the surgeon's experience on the rate of SSI. Wurtz et al. explored the possible difference in the rates of class I SSI for "new surgeons" having finished training within 6 months of joining the staff, "new-experienced surgeons" having finished training more than 6 months prior to joining the staff, and "experienced surgeons" on the staff for at least 5 years [21]. They found "new surgeons" to have higher SSI rates than their more experienced colleagues in two surgical subspecialities with infection-prone procedures and to take longer in the operating room despite the lack of any significant difference in patients' average ASA score. The cumulative number of cases and the SSI rate were negatively correlated. In cesarean sections, for example, a resident acting as a lead surgeon was found to be an independent risk factor for endometritis [22]. The rate of postoperative endometritis for attending physicians, chief residents, and residents was 6%, 12%, and 24%, respectively. In mastectomies, by contrast, surgical experience (67 operations performed by registrars, 58 by senior registrars, 21 by part-time consultants, and 18 by professors) was found to have no significant impact on complications [23]. No differences were observed in the percentage of infection, seromas requiring aspiration, wound breakdown, length of hospital stay, or cost.

In a prospective randomized study of the infection rate at the vena saphena harvesting site for coronary artery bypass grafting, no difference was found when an additional subcutaneous suture line was made by a single experienced physical assistant. The infection rate recorded for the control group, however, which consisted a number of surgical residents, was significantly higher [24], although it is not clear from the report whether the residents were supervised. In first ventriculoperitoneal shunt implantations performed between 1989 and 2001, the infection rate was significantly higher in patients treated by less experienced surgeons than in those treated by more experienced surgeons [25].

In the present study multivariable analysis showed significantly higher surgical site infection rates in the presence of risk factors such as age, pre-existing infections other than SSI, clean-contaminated or contaminated wounds, and BMI $\geq$30 kg/m^2. None of these results is unexpected, for they are patient-related. Exceeded T-time, a surgeon-dependent risk factor, was also identified as a risk factor in both univariable and multivariable analysis. The significant difference in SSI rate between visceral surgery, vascular surgery, and traumatology in univariable analysis was no longer significant in multivariable analysis. This reflects the difference in contributing risk factors for SSI. In traumatology, most of the wounds are clean and therefore at lower risk for SSI. In contrast, patients with arteriopathy are likely to present some of the risk factors such as high ASA class, diabetes mellitus, tobacco use, or obesity, and are therefore at higher risk for SSI.

The present study is subject to certain limitations. First, it is not a randomized, controlled trial. As Tables 1 and 2 show, patient characteristics and types of intervention were not equally distributed between the tutorial assistance and autonomous surgery groups. Rather, the distribution denotes the careful and individual selection of patients and the types of intervention in which tutorial assistance was regarded to be feasible. Multivariable analysis including 13 patient and procedural characteristics was used to take this difference into consideration when interpreting the data. However, because of the observational nature of this study, residual confounding by characteristics not recorded and therefore not accounted for in the analysis cannot be excluded.

Second, long-term outpatient follow-up data were not recorded prospectively, although information was collected from a very large sample with a high rate of outpatient follow-up data on the post-discharge development of SSI.

Conclusions

In carefully selected interventions, teaching assistance under supervision of a fully trained surgeon does not result in a higher rate of SSI. While other forms of training are useful, in-theater tutorial assistance continues to be the mainstay of surgical education.

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