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ORIGINAL REPORTS

Fingerprints of Teaching Interactions: Capturing and Quantifying How Supervisor Regulate Autonomy of Residents in the Operating Room

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OBJECTIVE: Supervisors and residents agree that entrusted autonomy is central to learning in the Operating Room (OR), but supervisors and residents hold different opinions about entrustment: residents regularly experience that they receive insufficient autonomy while supervisors feel their guiding is not appreciated as teaching. These opinions are commonly grounded on general experiences and perceptions, instead of real-time supervisors' regulatory behaviors as procedures unfold. To close that gap, we captured and analyzed when and to what level supervisors award or restrain autonomy during procedures. Furthermore, we constructed *fingerprints*, an instrument to visualize entrustment of autonomy by supervisors in the OR that allows us to reflect on regulation of autonomy and discuss teaching interactions.

DESIGN: All interactions between supervisors and residents were captured by video and transcribed. Subsequently a multistage analysis was performed: (1) the procedure was broken down into 10 steps, (2) for each step, type and frequency of strategies by supervisors to regulate autonomy were scored, (3) the scores for each step were plotted into fingerprints, and (4) fingerprints were analyzed and compared.

SETTING: University Medical Centre Groningen (the Netherlands).

PARTICIPANTS: Six different supervisor-resident dyads.

RESULTS: No fingerprint was alike: timing, frequency, and type of strategy that supervisors used to regulate autonomy varied within and between procedures. Comparing fingerprints revealed that supervisors B and D displayed more overall control over their program-year 5 residents than supervisors C and E over their program-year 4 residents. Furthermore, each supervisor restrained autonomy during steps 4 to 6 but with different intensities.

CONCLUSIONS: Fingerprints show a high definition view on the unique dynamics of real-time autonomy regulation in the OR. One fingerprint functions as a snapshot and serves a purpose in one-off teaching and learning. Multiple snapshots of one resident quantify autonomy development over time, while multiple snapshots of supervisors may capture best teaching practices to feed train-the-trainer programs. (J Surg Ed 000:1−12. © 2020 Published by Elsevier Inc. on behalf of Association of Program Directors in Surgery.)

KEY WORDS: entrustment of autonomy, teaching in the operating room, improving the learning climate, quantifying autonomy development

COMPETENCIES: Practice-Based Learning and Improvement, Professionalism, Patient Care

INTRODUCTION

Supervisors guide their residents during surgical procedures.[1] They stay the course from the moment they entrust

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residents with the scalpel, subsequently overhearing and overseeing the residents' actions.[1,2] From this stance, they assess whether they need to intervene and restrict residents' autonomy to ensure optimal patient outcome.[1-3]

Supervisors and residents consider entrusted autonomy as the key didactic principle to master surgical procedures.[1-8] In an optimal learning environment, supervisors adapt the level of entrusted autonomy to the residents' learning needs.[3] In general, residents experience that supervisors entrust them with insufficient autonomy.[8] Supervisors, on the other hand, believe that they entrust appropriate levels of autonomy to match the residents' learning needs,[9-11] yet often feel that residents fail to recognize their guidance as teaching.[12-15] This mismatch in opinions about learning needs and levels of entrusted autonomy is grounded in perceptions and not substantiated by data from real-time teaching interactions in the OR.

In reality, levels of entrusted autonomy vary between supervisors and within procedures.[1,16] For simple procedures, supervisors increase autonomy according to the resident's seniority, but for complex procedures such linearity in entrustment seems less evident.[17] Some authors show that individual preferences of supervisors affect levels of entrusted autonomy.[1,18,19] Congruent personalities within a dyad increase the level of entrusted autonomy and vice versa.[20] Although the dynamics of entrusted autonomy during surgical procedures are widely recognized, they are only partially explained and their mechanisms are poorly understood.

Chen et al conducted an interview study to investigate how dedicated supervisors restrict autonomy during surgical procedures.[3] They concluded that decisions to restrict autonomy are rather ad hoc and triggered by signals of insufficient competency. Based on their data, they constructed a conceptual 3-step model of how supervisors make decisions to restrict autonomy. They continuously monitor residents, and triggered by their performance (step 1) they assess their entrustability to execute the task at hand (step 2). Based on that assessment, supervisors determine whether and how much of residents' autonomy needs to be restricted to complete a step of the procedure (step 3).[3] Nieboer et al analyzed real-time supervisors' behaviors in the operating room,[2] showing that supervisors remained attentive and monitored how residents progressed (*watchful waiting*). They also showed that supervisors used 9 different strategies to intervene and restrict autonomy during surgical procedures. The strategies of this supervisor's toolkit range from explicitly inspecting the recent activities of residents (and restrict minimal autonomy) to taking over all activities and entrusting no autonomy to residents.[2] Both studies contributed to the understanding of real-time, autonomy-regulating interactions between supervisors and residents, insights which are considered as essential to improve learning in the OR.[8] And yet, neither study captured the dynamics of entrustment in real time.[2,3]

In this study, we present a new conceptual framework to analyze supervision behaviors (fingerprints). Fingerprints visualize and quantify timing, type, frequency, and distribution of strategies that 6 supervisors used to regulate entrusted autonomy throughout an uncemented total hip arthroplasty. Furthermore, we demonstrate how fingerprints may contribute in analyzing entrustment of autonomy within and between supervisor-resident dyads.

METHODS

Setting and Participants

The study was conducted at University Medical Center Groningen in the Netherlands. Six different supervisors guided 6 residents during an uncemented total hip arthroplasty. This procedure was selected because it is highly standardized yet also involves crucial decisions that carry substantial medical risks. All supervisors started the procedure as assistants.

We took a convenience sample of 6 dyads (supervisor and resident) from our everyday practice (Table 1). In our hospital, supervisors with different backgrounds guide residents (eg, orthopedic surgeons, senior residents, and physician assistants). Two of the supervisors were experienced orthopedic surgeons, one was an orthopedic surgery fellow (in year 1 after finishing residency), and one was a senior resident in PY6 (program

TABLE 1. Dyads Participating in This Study

Supervisor	Gender	Resident (Year of Training)	Gender	Procedure (hours/min/sec)
A: Orthopedic surgeon	Male	PY 2	Female	36 min/07 s*
B: Orthopedic surgeon	Male	PY 5	Male	1 h/33 min/07 s
C: Orthopedic surgery fellow	Female	PY 4	Male	1 h/26 min/04 s
D: Orthopedics senior resident	Male	PY 5	Male	/01 min/25 s
E: Physician assistant	Male	PY 4	Male	1 h/03 min/55 s
F: Physician assistant	Male	PY 6	Male	58 min/38 s

*Supervisor took over procedure.

year). Two supervisors worked as physician assistants. Physician assistants in our institution receive specific training to assist surgeons in total hip replacement surgery, and only guide residents who have demonstrated sufficient progress. In the Netherlands, the training program last 6 years: residents start with an 18-month rotation in general surgery, followed by multiple rotations at different teaching hospitals. The 6 residents in this study ranged from PY2 to PY6.

Each supervisor, resident, patient, and OR team member was informed about the goal of the study and written consent was obtained. The ethical review board of our hospital discussed the study and confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply.[21] We followed the Helsinki Declaration of medical research for all participants in this study.[22]

Analysis

All procedures were videotaped and transcribed. For further analysis, we used a multistage approach. The first stage was to identify the relevant steps of the UTHA procedure. To this end, we used the task analysis reported in a previous study.[23] This yielded an analysis of the procedure consisting of 10 overarching steps: (1) superficial exposure; (2) deep exposure; (3) collum osteotomy; (4) prepare acetabulum; (5) insert definitive cup; (6) prepare the femur; (7) insert definitive stem; (8) combine cup and stem; (9) close deep wound layers; and (10) close subcutis and skin (Appendix 1). In the second stage, we identified supervisors' actions to restrict autonomy for each step of the procedure and scored type of strategy according to the supervisor's toolkit to regulate autonomy (Table 2).

In the final stage, we plotted these scores for each step in a diagram or *fingerprint* where the different strategies are displayed in different shades. The more autonomy is restricted, the deeper the shade of a bar in the fingerprint.

RESULTS

In this section, we first cover overall scores of supervision strategies for each supervisor, and give the distribution over the 4 major types of actions: evaluating progress, managing decision-making, adjusting motor actions, and taking over. Next, the fingerprint for each supervisor is presented and its dynamics described. At the end, we compare supervisors along 2 axes: more or less control, and differences in dynamics.

TABLE 2. The Supervisor's Toolkit to Regulate Autonomy[2]

Type of Action	Strategy of Supervisor	Effect on Autonomy of Resident	
Evaluate progress	1. Inspection of the previous activity (looking into/ palpating the operation field)	Residents are allowed to make their own evaluations, but are not allowed to continue until supervisors completed their evaluation.	Minimal restriction
Maximum restriction			
	2. Request for information	Residents are allowed to make their own evaluations but have to verbalize that evaluation before they are allowed to continue.	
	3. Express an expert opinion	Residents have to take the supervisors' opinion about the progress into account for their own evaluations.	
Decision-making	4. Explore the next decision	Residents have the autonomy to make decisions by themselves but have to make them controllable by verbalizing their decisions.	
	5. Suggest the next decision	Residents do not make decisions by themselves. Suggestions allow residents to verbalize an alternative decision. Residents and supervisors negotiate a final decision.	
	6. Declare the next decision	Supervisors unilaterally decide what the next action should be. Residents are not allowed any autonomy to make decisions themselves and need to proceed according to the supervisor's plan.	
Motor action	7. Adjust the manual action (verbally or nonverbally)	Residents execute a decision and supervisors subsequently correct the course of action, either verbally or manually.	
	8. Stop the manual action	Supervisors stop the manual activity of residents.	
Evaluation + decision-making + motor action	9. Take over	Supervisors literally take over the scalpel and residents continue as assistants.	

Supervisor A

Supervisor A, an orthopedic surgeon, entrusted a PY2 resident with the scalpel until he took over during step 3 (Fig 1. Fingerprint A). In the first step, he used 44 strategies overall, 12 of them to evaluate progress, 12 to manage decision-making, and 15 to adjust the motor action of the resident. Supervisor A took over at 5 instances for the following reasons: to re-established the correct plane of dissection (3×), to expose the surgical field to evaluate the procedure's progress (1×), and to take over completely. Specific information on time, type, and frequency of strategies employed by supervisor A can be seen in Figure 1.

Supervisor A exhibited a high number of strategies that adjust ongoing actions of the resident from the start of the operation until he took over the procedure in step 3. He was especially involved in decision-making during steps 2 and 3. Overseeing the 3 steps, supervisor A displayed a rather continuous level of control over the resident.

Supervisor B

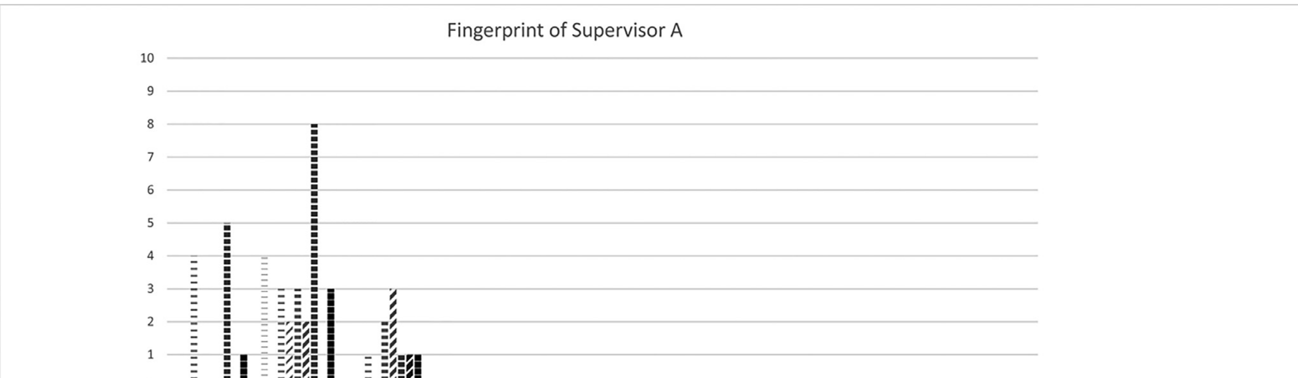
Supervisor B, an orthopedic surgeon that guided a PY5 resident, used 158 strategies overall: 107 strategies to evaluate progress, 47 to manage decision-making, and 7 to adjust motor actions. He took over 7 times, usually to evaluate the procedure's progress. At one point, he ordered the resident to switch places and revised the reaming task and insertion of the trial prosthesis himself. Figure 2 shows the variation in supervision over the procedure.

In steps 9 and 10, supervisor B left the resident to continue unattended, in contrast to step 4, when he unilaterally decided to switch places and revise the reaming of the acetabulum himself. Especially during steps 2 and 4 but also in step 6, he kept a close watch of the procedure's progress. Decision-making interventions intensified in step 4 and increased further in steps 5 and 6.

Supervisor C

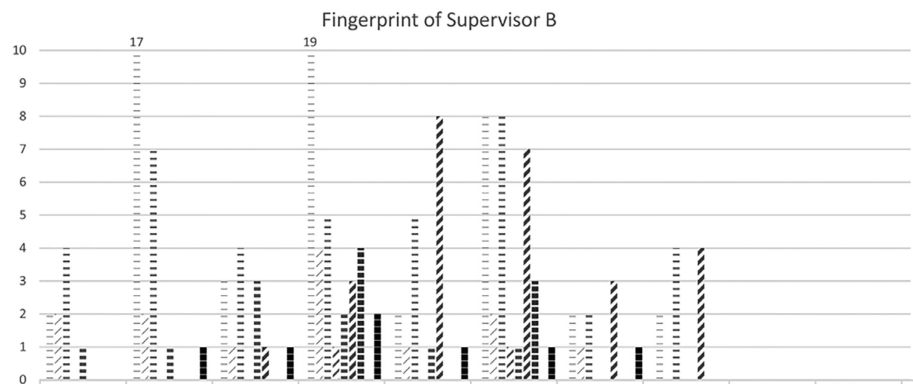
In this procedure, an orthopedic surgery fellow supervised a PY4 resident. She attended the entire procedure and used 70 strategies to restrict autonomy. The strategies were distributed as follows: evaluation: 40, decision-making: 21, motor actions: 5, taking over: 4. Taking over was very brief and restricted to minor portions of the procedure, usually to get a better overview of the procedure's progress. The supervision dynamics of supervisor C are presented in Figure 3.

There is a low frequency of supervision strategies in steps 1 to 3, 5, and 7 to 10. In those steps supervisor C did not explicitly use strategies that instruct (declare decision-making) or correct (adjust ongoing motor action) the resident, in contrast to steps 4 and 6. In those steps, she shifted type and number of strategies that restrict the resident's autonomy more explicitly. She used suggestions quite often, in doing so inviting the resident to a process of shared decision-making for those steps.



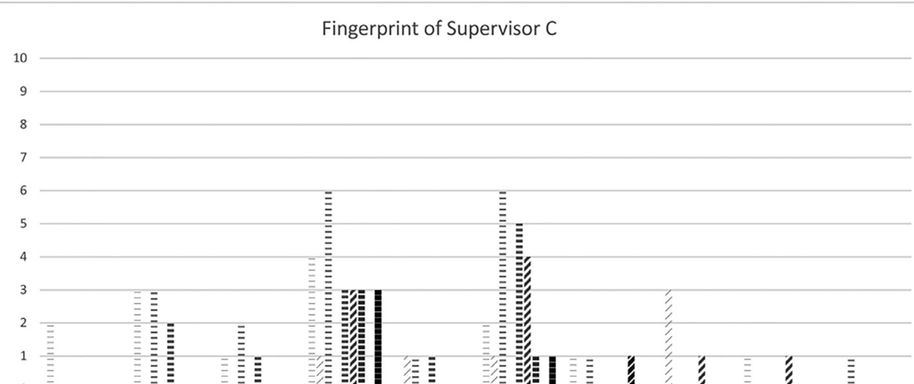
	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect		4									4	Evaluate progress (EP)
Request information											0	
Expert opinion	4	3	1								8	
Explore decision		2									2	Decision-making (DM)
Suggest decision		3	2								5	
Declare decision		2	3								5	
Adjust manual action	5	8	1								14	Motor action (MA)
Stop manual action			1								1	
Take over	1	3	1								5	EP + DM + MA
Total	10	25	9	0	0	0	0	0	0	0	44	

FIGURE 1. Fingerprint of supervisor A.



	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect	2	17	3	19	2	8	2	2			55	Evaluate progress (EP)
Request information	2	2	1	4	1	2	1				13	
Expert opinion	4	7	4	5	5	8	2	4			39	
Explore decision				1		1					2	Decision-making (DM)
Suggest decision	1	1	3	2	1	1					9	
Declare decision			1	3	8	7	3	4			26	
Adjust manual action				4		3					7	Motor action (MA)
Stop manual action												
Take over		1	1	2	1	1	1				7	EP + DM + MA
Total	9	28	13	40	18	31	9	10	0	0	158	

FIGURE 2. Fingerprint of supervisor B.



	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect	2	3	1	4		2	1		1		14	Evaluate progress (EP)
Request information				1	1	1		3			6	
Expert opinion		3	2	6	1	6	1			1	20	
Explore decision												Decision-making (DM)
Suggest decision		2	1	3	1	5					12	
Declare decision				3		4		1	1		9	
Adjust manual action				3		1					4	Motor action (MA)
Stop manual action							1				1	
Take over				3		1					4	EP + DM + MA
Total	2	8	4	23	3	20	3	4	2	1	70	

FIGURE 3. Fingerprint of supervisor C.

Supervisor D

Supervisor D was a PY6 resident and guided a PY5 resident. He used 74 strategies to evaluate progress, 44 to manage decision-making and 16 to redirect the hand during motor actions, taking over once (in total 135 strategies). Supervisor D took over with the intention to optimize his evaluation of how the procedure evolved. How supervisor D varied number and type of strategies is shown in Figure 4.

There is a low-high-low pattern of supervisor involvement during this procedure. The peak of supervision behavior is in step 4—after steps 1 to 3—with an increase in number and type of strategies that evaluate, manage decision-making and adjust ongoing actions of the resident. In step 5, there is a decline in supervision behavior, peaking again during step 6 before strongly decreasing in steps 7 to 9. In step 10, supervisor D stepped out and let the resident close the wound unattended.

Supervisor E

Supervisor E, a physician assistant, collaborated with a PY4 resident in this procedure. He supervised the resident in all the steps of the procedure, using 44 strategies overall: 19 to evaluate, 16 to manage decisions, 6 to adjust motor actions, and 3 to take over. The supervision dynamics of supervisor E are displayed in Figure 5.

This fingerprint shows that supervisor E employed more strategies and used more restrictive types of strategies in steps 4 and 5 in contrast to steps 6 and 7, where he used fewer strategies and allowed the resident more autonomy. Even less restrictive supervision behavior was seen in steps 3, 8, and 9. There was no supervisor interference in steps 1, 2, and 10.

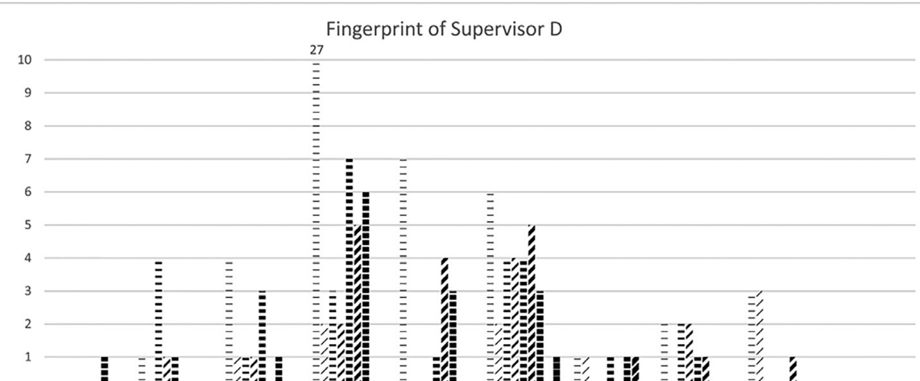
Supervisor F

A second physician assistant supervised a PY6 resident in this procedure and employed a total of 50 strategies to guide the resident through the 10 steps. The majority of strategies[36] involved evaluation of the procedure's progress. He used 9 strategies to manage decisions, 2 to adjust motor actions, and 3 to take over briefly in order to gain better understanding of the progress. Figure 6 represents the supervision behavior of supervisor F.

An increase in resident guidance by supervisor F was particularly seen in steps 4 and 6, although in the latter step fewer strategies were used to address decision-making. No supervision strategies were witnessed in steps 1 and 10. In steps 5, 7, and 8 the supervisor just used strategies to evaluate progress, peaking in step 5, and in steps 2, 3, and 9 he used fewer strategy types.

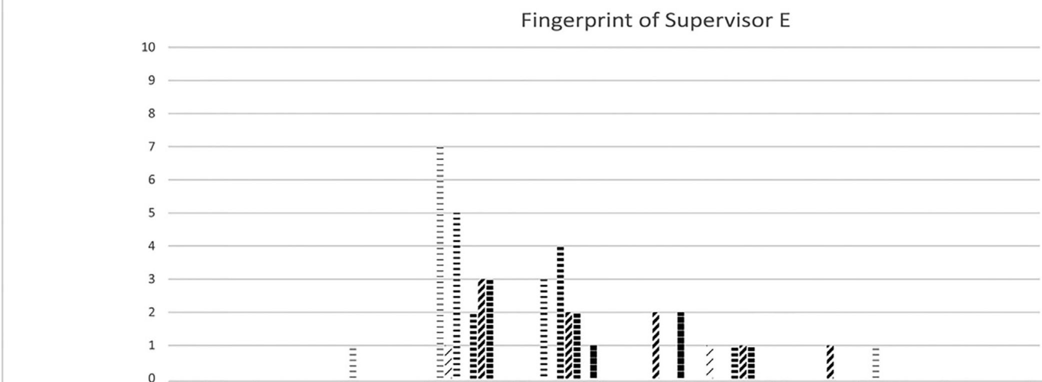
Comparing Supervisors

Fingerprints allow us to compare the dynamics of supervision within dyads, as well as the use of supervision



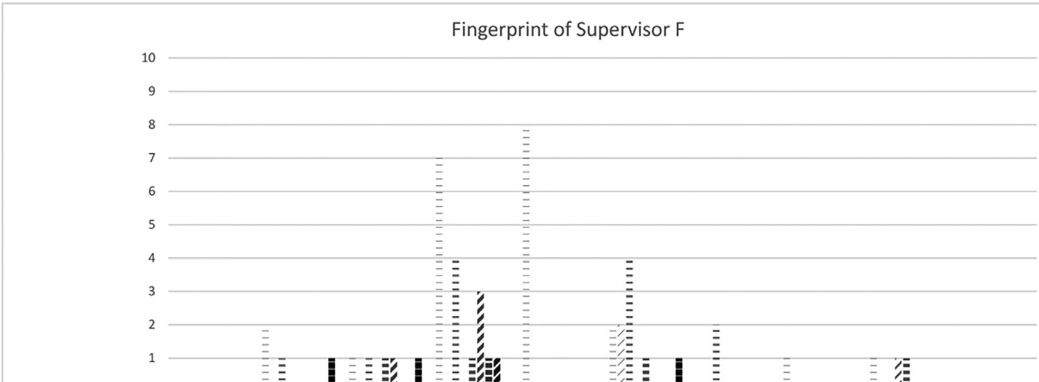
	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect		1	4	27	7	6	1	2	3		51	Evaluate progress (EP)
Request information			1	2		2	1		3		9	
Expert opinion		4	1	3		4		2			14	
Explore decision		1	1	2		4		2			10	Decision-making (DM)
Suggest decision		1	3	7	1	4	1	1			18	
Declare decision				5	4	5		1	1		16	
Adjust manual action	1		1	6	3	3	1				15	Motor action (MA)
Stop manual action							1				1	
Take over						1					1	EP + DM + MA
Total	1	7	11	52	15	29	5	8	7	0	135	

FIGURE 4. Fingerprint of supervisor D.



	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect	0	0	1	7					1		9	
Request information				1			1				2	Evaluate progress (EP)
Expert opinion				5	3						8	
Explore decision												
Suggest decision				2	4		1				7	Decision-making (DM)
Declare decision				3	2	2	1	1			9	
Adjust manual action				3	2		1				6	Motor action (MA)
Stop manual action												
Take over					1	2					3	EP + DM + MA
Total	0	0	1	21	12	4	4	1	1	0	44	

FIGURE 5. Fingerprint of supervisor E.



	1. Superficial exposure	2. Deep exposure	3. Collum osteotomy	4. Preparing acetabulum	5. Inserting cup	6. Preparing femur	7. Inserting stem	8. Combining cup and stem	9. Closure deep layers	10. Closure subcutis and skin	Total	
Inspect		2	1	7	8	2		1	1		22	
Request information						2					2	Evaluate progress (EP)
Expert opinion		1	1	4		4	2				12	
Explore decision									1		1	
Suggest decision			1	1		1			1		4	Decision-making (DM)
Declare			1	3							4	
Adjust manual action				1							1	Motor action (MA)
Stop manual action				1							1	
Take over		1	1			1					3	EP + DM + MA
Total	0	4	5	17	8	10	2	1	3	0	50	

FIGURE 6. Fingerprint of supervisor F.

strategies between dyads. We can compare different dyads along 2 axes: more or less control (selection of strategies from the toolkit) and variation in the use of these tools over time (dynamics of control).

On the control axis, supervisors A, B, and D are more on the control side of supervision. Supervisor A displayed the highest level of control, switching positions definitively during step 3 to perform the procedure himself. Supervisor B revised a part of a step of the procedure himself and used the highest number of strategies of all supervisors. Supervisor D used fewer strategies than supervisor B. Relatively on the other side of the axis are Supervisors C, E, and G: they all used fewer strategies than supervisors B and D and took over only for brief moments to gain better understanding of the procedure's progress.

Looking at the dynamics of control, we see that some supervisors show little variation in type and frequency between steps. Supervisor A used more and different strategies that restrict autonomy, while supervisor F used fewer and less varied strategies to restrict autonomy throughout the procedure. The fingerprints of supervisors B, C, D, and E display a more dynamic style of supervision, all showing more strategies in steps 4 to 6 than in the other steps. However, high-low contrasts vary between those supervisors. Supervisors B and D both left the OR at the end of the procedure and displayed the highest numbers of strategies to restrict autonomy in steps 4 to 6. Such contrasts were less marked for supervisors C and E.

DISCUSSION

In this study, we varied supervisors and residents using a convenience sample and let them perform one type of surgical procedure, an uncemented total hip arthroplasty. We captured and quantified real-time regulation of autonomy of supervisors in fingerprints. A fingerprint visualizes timing, type, and frequency of strategies that supervisors use to entrust autonomy. Each fingerprint shows that supervisor-regulated autonomy is a unique dynamic interactional process where entrustment fluctuates between 2 extremes: awarding residents autonomy to continue without any interference (the supervisor as watchkeeper that assists and monitors the resident), and taking over evaluation, decision-making, and motor actions of the resident (the supervisor as helmsperson).

Without exception, the supervisors took over activities of their resident, albeit with varying intentions. Some supervisors took over briefly, for instance to improve their evaluation or reset the course of the procedure. One supervisor revised a complete task of a step, another took over the procedure, no longer entrusting the scalpel to the resident. Any moment a supervisor takes over briefly, or more extensively, the resident becomes an assistant and changes learning: learning by observation instead of learning by doing.

Each fingerprint captured how a supervisor increased or decreased the grip on their resident in the course of the operation. Overseeing all fingerprints, supervisor A demonstrated the highest level of grip on his resident, while supervisor F awarded the resident the highest levels of autonomy. Supervisors B and D are more positioned toward supervisor A (relatively restrictive autonomy), while supervisors C and E are nearer supervisor F (relatively awarding autonomy). Experience level of the residents obviously explains differences in supervisors' behaviors. Supervisor A guided the least experienced and supervisor F the most experienced resident—and yet supervisors B and D, who guided PY5 residents, used more, and more explicit strategies to restrict autonomy than supervisors C and E, who guided PY4 residents.

Although experience of the resident has a major impact on levels of entrustment, more aspects explain variance in supervisor's entrustment as well.[1,7,8] Restriction of entrustment is more likely when the supervisors' have less confidence with the procedure and when they have difficulty to assess the resident's level of expertise.[3,19,24,25] Understandably, in our sample both the PY6 resident (supervisor D) and fellow (supervisor C) lack the experience of the orthopedic surgeons (supervisors A and B) and physician assistants (supervisors E and F). Interestingly, orthopedic surgeon B and PY6 resident D showed the highest frequencies of autonomy-restricting strategies.

Multiple other factors can prompt supervisors to restrict autonomy. They will obviously reduce the level of entrusted autonomy when residents fail to acknowledge their own limitations.[1,3,11] Previous literature has shown that supervisors' individual preferences and time constraints inform their choice to restrict autonomy.[1,3,19,24,25] Interpersonal factors between individual supervisors and residents play a role too (eg, the quality of the working relationship outside the OR, compatibility of personalities, trust, etc.).[24-29] Residents' stress, lack of confidence, and exhaustion have also been found to decrease levels of entrustment.[10,30,31]

Understanding what explains supervisors to restrict autonomy at specific moments is important. However, even more important is whether supervisors make the correct assessments of the level of autonomy that can be entrusted to their residents in particular situations, especially during complex tasks. Entrusting residents with more autonomy than they are capable of may endanger patient outcome and decrease the residents' self-confidence.[1,32] Underestimating the residents' expertise and restricting too much autonomy decelerates learning curves and may be demotivating.[1,9,32,33] Conversely, correct assessment of experience of residents ensures both optimal patient outcome and learning.

Supervisors B to F all restricted more autonomy of residents in steps 4 to 6 than in the other steps of the procedure. This is not unexpected, as those steps incorporate important, point-of-no-return tasks that influence patient outcome.[23] Guiding residents in steps 4 to 6 will initiate a teaching/patient outcome paradox: supervisors have to entrust residents with maximum levels of autonomy in point-of-no-return tasks before residents continue as independent licensed surgeons. Still, supervisors tend to restrict autonomy when margins of error are rather narrow.[1]

Fingerprints as a Tool to Improve the Learning Climate

Fingerprints are like snapshots of teaching interactions in the OR, and embody concrete quantitative data for supervisors and residents, enabling discussion of residents' task performance and analysis of whether mismatches between learning needs and levels of entrustment occurred in the course of the procedure. Fingerprints can serve a purpose in one-off teaching encounters or used as a tool to analyze supervisors and residents over time.

A Single Snapshot of One Teaching Encounter

Fingerprints represent when, how, and to what level a supervisor did entrust autonomy in a specific dyad. A fingerprint can expand the focus of postoperative debriefings of supervisors and residents, which usually more focus on resident's performances than on the learning climate.[34] Fingerprints can be a ground to reflect on why entrustment was managed by supervisors at particular moments, and to analyze whether levels of entrustment matched or mismatched learning needs. Understandably, reflecting on all steps of the procedure is rather impractical in one-off teaching encounters. Selecting one representative, for instance, a complex step to reflect on provides rich and relevant information to assess a resident's level of autonomy and to discuss if teaching was effective, information that may help to improve learning and teaching in future procedures.

Multiple Snapshots of Teaching Encounters Over Time

Fingerprints can also be used in 2 other teaching modalities. Best practices of teaching of supervisors can be identified when comparing fingerprints of a specific supervisor who guides different residents through one single type of surgical procedure. Fingerprints of role model supervisors crafted in this way can shed light into specific teaching behaviors that role-model supervisors employ to guide residents, and reveal best practices to inform train-the-trainer programs.

Alternatively, comparing fingerprints of one resident and performing one type of procedure guided by different supervisors may identify the resident's learning strategy. When focusing on how different supervisors (longitudinally) entrust autonomy to an individual resident over time, we can also determine learning curves of the resident. Such information is particularly relevant to ground assessments of entrustable professional activities, a system to determine if and to what degree supervisors are allowing a resident to perform specific activities autonomously.[35-37] Finally, as curricula in the surgical specialties evolved toward competency-based programs, repetitive fingerprints of all residents can provide information on whether endpoints of modern competency-based curricula in a teaching hospital are being met.

Limitations

There are limitations to acknowledge in this study, such as selection, cultural aspects, and sample size. The supervisors and residents reflect the local culture of training and learning in one single teaching hospital in the Netherlands. Insights into the strategies to regulate autonomy are necessary to fingerprints. Another point is transferability of results. It would be interesting to investigate whether fingerprints could be a fruitful contribution to the learning climate in other procedures and other cultures. The present study's approach of constructing fingerprints of real-time interactions in the OR provides a framework to analyze supervisor-resident interactions in other procedures and settings.

CONCLUSION

Supervisors continuously increase and decrease the grip over their residents in the OR, and dynamics of entrustment vary within and between supervisor-resident dyads. Fingerprints capture those dynamics and quantify when and to what degree supervisors restrict autonomy of their residents during surgical procedures. Fingerprints provide a tool to reflect on teaching in one-off learning encounters, analyze best practices of supervisors, assess residents' levels of proficiency and analyze their learning curves.

APPENDIX

Table A1

TABLE A1. Steps and Tasks of an Uncemented Total Hip Arthroplasty, Posterior Approach

Step 1 Superficial exposure (Tasks 1-5)	
1A	Assess location of skin incision
1B	Incise skin and subcutaneous tissues
1C	Hemostasis of skin and subcutaneous tissues
1D	Assess location and incision of fascia lata
1E	Incise gluteal maximus muscle
Step 2 Deep exposure (tasks 6-12)	
2A	Identify exorotator muscles
2B	Incise exorotator muscles (except for piriformis muscle)
2C	Incise and place a suture in piriformis muscle
2D	Expose hip capsule
2E	Insert homan retractors behind gluteal medius muscle
2F	Incise joint capsule
2G	Luxate hip joint
Step 3 Collum osteotomy (tasks 13-19)	
3A	Expose collum
3B	Insert homan retractors
3C	Expose osteotomy location of collum
3D	Assess angle and height of collum femoris osteotomy
3E	Perform collum osteotomy
3F	Evaluate and assess collum osteotomy
3G	Remove caput femoris from acetabulum
Step 4 Prepare the acetabulum (tasks 20-23)	
4A	Expose acetabulum with homan retractors/steinman pins
4B	Excise labrum, remove tissue fovea
4C	Ream acetabulum in right angle, correct depth and width
4D	Insert trial acetabular component and assess optimal size
Step 5 Insert definitive acetabular component[24,25]	
5A	Insert definitive acetabular component
5B	Assess position of definitive acetabular component
Step 6 Prepare the femur[26-32]	
6A	Expose femur with homan retractors
6B	Prepare proximal femur canal to facilitate insertion of reamers
6C	Insert straight canal reamers in ascending order
6D	Assess anteversion angle of femoral component
6E	Broach proximal femur in ascending order
6F	Insert trial femoral component and assess position and offset
6G	Assess definitive femoral component size
Step 7 Insert definitive femoral component (tasks 33-34)	
7A	Insert definitive femoral component
7B	Assess position, anteversion angle and depth of femoral component
Step 8 Combine femoral and acetabular components (tasks 35-40)	
8A	Insert trial head component
8B	Reduce hip joint
8C	Assess stability and range of motion
8D	Insert definitive head component
8E	Reduce femur
8F	Assess stability
Step 9 Close deep wound layers (tasks 41-43)	
9a	Reconstruct joint capsule
9b	Reconstruct piriformis muscle/exorotator muscles
9c	Reconstruct m. Gluteus maximous/fascia lata
Step 10 Close subcutis and skin (tasks 44-45)	
10a	Reconstruct subcutaneous tissues
10b	Close skin

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