Complex aortic aneurysm management: from technical outcomes to patient-centered insights

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PART 1

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CHAPTER 1

Learning curve ana endovascular aorti

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ABSTRACT

Objectives

When introducing new techniques, attention must be paid to learning curve. Besides quantitative outcomes, qualitative factors of influence should be taken into consideration. This retrospective cohort study describes the quantitative learning curve of complex endovascular aortic repair (EVAR) in a non-high volume academic center and provides qualitative factors that were perceived as contributors to this learning curve. With these factors, we aim to aid in future implementation of new techniques.

Methods

All patients undergoing complex EVAR in the Leiden University Medical Center (LUMC) between July 2013 and April 2021 were included (n=90). Quantitative outcomes were: operating time, blood loss, volume of contrast, hospital stay, major adverse events (MAE), 30-day mortality, and complexity. Patients were divided into three temporal groups (n=30) for dichotomous outcomes. Regression plots were used for continuous outcomes. In 2017, the treatment team was interviewed by an external researcher. These interviews were re-analyzed for factors that contributed to successful implementation.

Results

Length of hospital stay (p= 0.008) and operating time (p= 0.010) decreased significantly over time. Fewer cardiac complications occurred in the third group (3: 0% vs. 2: 17% vs. 1: 17%, p= 0.042). There was a trend of increasing complexity (p=0.076) and number of fenestrations (p= 0.060). No significant changes occurred in MAE and 30-day mortality. Qualitative factors that, according to the interviewees, positively influenced the learning curve were: communication, mutual trust, a shared sense of responsibility and collective goals, clear authoritative structures, mutual learning, and team capabilities.

Conclusions

In addition to factors previously identified in the literature, new learning curve factors were found (mutual learning and shared goals in the OR), that should be taken into account when implementing new techniques.

INTRODUCTION

Originally introduced in aircraft manufacturing, learning curve studies addressed the variation in costs and labor time, when production quantity increased.[1] A learning curve can provide information on different levels: whether learning has taken place, at which rate, whether a desired level of performance has been reached, and whether learning has stopped or even regressed. A classic learning curve (Figure 1) is comprised of three phases; an initial gentle slope, followed by a phase of rapid learning, ending in a plateau phase when additional procedures no longer improve performance. Reaching the plateau phase can either mean learning has stopped and adjustments should be made in order to improve again, or that an expert plateau phase or target values have been reached. More recently, a period of regression or decline has been added as a potential fourth phase. Here, competence decreases due to an increase in challenging cases or due to 'unlearning'.[2-4]

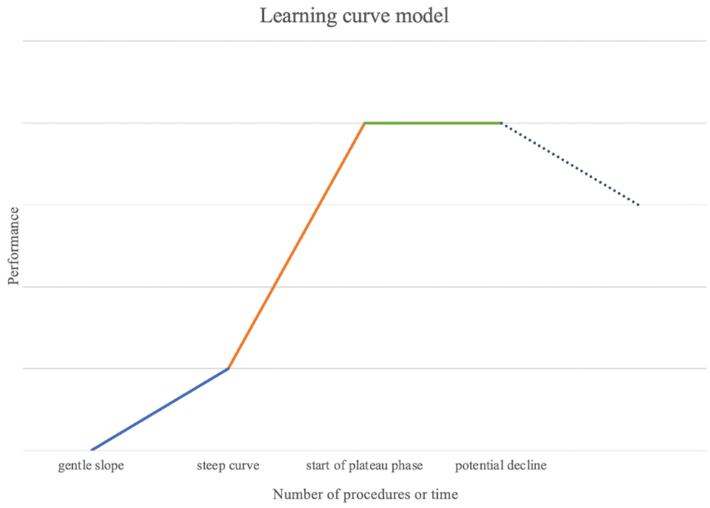


Figure 1: Learning curve model.

In order to optimize implementation of new surgical techniques, it is important to examine factors that contribute to a successful learning curve. Several technical factors have been established, such as a surgeon's manual dexterity and the experience of the supporting surgical team.[2-3,5] Besides technical skills, deliberate team selection and a shared mental model of motivation are vital. In addition, a balance should be sought between authoritative leadership and a safe environment, in which all team members feel free to communicate their thoughts.[6] Another important factor is team stability, which enhances relational competence; knowledge of individual team members' preferences, and the way team roles relate to each other. However, when procedures become too much of a routine, adapting to change becomes difficult. This can be addressed by performing trials of new routines, to prevent 'unlearning'.[7]

Establishing a learning curve is common practice in robotic and minimally invasive surgery. Switching from an established standard to a technically challenging new approach requires justification, and is therefore particularly suited for learning curve analyses.[3,8-9] In the field of vascular surgery, complex endovascular aortic repair (complex EVAR) represents such a development. Complex aortic aneurysms extend up to or above the renal arteries, involving visceral and arch branches that need to be incorporated in the reconstruction. For decades, open reconstruction was the standard of treatment, albeit associated with significant morbidity and mortality.[10-11] Treatment options greatly expanded with fenestrated EVAR (FEVAR) and branched EVAR (BEVAR).[12] The application of this technique is expected to grow further, due to technical innovation.[13] Complex EVAR is technically more demanding than conventional EVAR; stent grafts are tailor-made for each patient, implantation is supported by advanced imaging tools, high-end operating facilities are necessary, and it requires a treatment team to adopt new skills. These complex techniques were pioneered in high-volume aortic centers of excellence, and the most robust outcome data derives from their results.[14-16]

Previously, learning curves were established for branched-fenestrated EVAR implementation in the United States, for the experience of a single surgeon, and for the usage of a specific device.[17-19] These studies focused on the quantitative aspect, as is often the case for surgical learning curves. The current study focuses on the qualitative aspect of implementing complex EVAR and presents quantitative outcomes in a non-high-volume hospital. By establishing factors that positively contributed to team-learning, we aim to support future implementation of new techniques; not just in endovascular surgery, but in other surgical fields as well.

METHODS

Complex EVAR implementation

In July 2013, the first complex EVAR procedure was performed in the Leiden University Medical Center (LUMC); a tertiary referral center for aortic pathology. To optimize the implementation of complex EVAR, a dedicated endovascular treatment team (ETT) was composed, consisting of vascular surgeons, interventional radiologists, thoracic surgeons, anesthesiologists, clinical neurophysiologists, radiology technicians, and scrub nurses. Great attention was paid to team composition; members were selected based on self-professed interest, capabilities, and time commitment. All interventional radiologists and vascular surgeons had previous experience with conventional EVAR.

Prior to surgery, each patient was discussed in a multidisciplinary consultation. Complex EVAR stents were designed for each individual patient based on CT-imaging by the interventional radiologists, vascular surgeons, and stent graft manufacturers. The first four procedures were proctored. Postoperative care was planned by consulting selected ICU specialists and internal medicine doctors. Seven of the initial twenty members left the team due to job changes or retirement: a scrub nurse (2019), radiology assistant (2018), industry representative (2017), two thoracic surgeons (2019, 2018), anesthesiologist (2018), radiology product expert (2017). Eight members joined the team: a scrub nurse (2019), radiology assistant (2018), industry technician (2017), thoracic surgeon (2019), two anesthesiologists (2018, 2017), radiology product expert (2017), and a vascular surgeon (2020).

Data collection

A single-center retrospective study was performed. All patients who had undergone complex (thoraco-)abdominal EVAR in the LUMC between July 2013 and April 2021 were included. Solitary thoracic EVAR (TEVAR) procedures were excluded. Patients received standard of care follow-up, in accordance with our institution's protocol. They were seen in the outpatient clinic by the vascular surgeon at 6 weeks, 6 months, 12 months, and yearly after that. CT-angiography, duplex ultrasonography, and abdominal X-ray were used to monitor aneurysm or stent graft related complications. For the quantitative analysis, data were subtracted from patients' medical records, and stored in a secured computerized secure database. Data collection was approved by the institution's Medical Ethics Committee (METC).

In 2017, when 46 complex EVAR procedures had been performed, semi-structured face-to-face interviews were conducted with all 19 ETT members by an external interviewer, in order to monitor the implementation phase.[20] The main goal was to identify what every team member needed in order to adequately fulfil their task. These interviews were re-examined for the qualitative analysis of the current study. All interviews were conducted within an 11-day period during which no complex EVAR procedures were conducted, in order to avoid recency bias between the interviewees. Each interview lasted between 50 and 100 minutes. Questions are added in Appendix A. The interviews were transcribed and coded using Atlas.ti software. ETT members' reflections were captured in first order codes that closely followed the phrasing used by interviewees. Factors were considered to be vital to the procedure if they were mentioned at least ten times by at least five different interviewees. First order codes were subsequently grouped into second order codes by the external researcher. In a final step, the researcher aggregated the second order codes into three key dimensions: relational embedding, cognitive embedding, and team learning. Factors that influenced the learning curve according to interviewees were extracted from this data for the purpose of the current study. They were compared with factors derived from literature. Corresponding and supplementary factors are discussed in this paper.

Outcome measures

Surgical outcomes were initial technical success (achieved if all arteries were successfully treated as planned), operating time (minutes), blood loss (milliliters), fluoroscopy time (minutes), and volume of contrast (milliliters). Clinical patient outcomes were length of hospital stay (days), discharge to a rehabilitation center, 30-day mortality, major adverse events (MAE; complications with a Clavien-Dindo score of III-IV), the necessity of endoleak repair, and reinterventions due to complications.[21] In order to monitor changes in complexity over the years, the ETT established a complexity coding scheme. Complexity levels were defined as 1 (least complex), 2, 3, and 4 (most complex). Level 1 included complex EVAR with 1 or 2 fenestrations. Level 2 included 3 or 4 fenestrated EVAR. Level 3 included al branched EVAR patients, and level 4 included branched-fenestrated EVAR combinations, arch EVAR, and emergency cases.[20] Scoring complexity based on the number of fenestrations is in accordance with previous research.[22-23]

Statistics

Patients were divided into three temporal groups: the first 30 patients (group 1), the second 30 patients (group 2), and the third 30 patients (group 3). These cut-off points are in accordance with previous research and were set before any analyses were made, in order to preclude bias resulting from data-dependent splitting.[24] Baseline characteristics and outcomes are presented as numbers and percentages for categorical data and as mean or median, with standard deviation or interquartile range respectively, for continuous data. Baseline characteristics were compared using the ANOVA F-test for continuous normally distributed data. The Fisher's exact test was used for dichotomous baseline data and categorical learning curve outcomes. In addition, Poisson regression analyses were made. The learning curve for continuous outcomes was established by calculating the regression coefficients, as this is the preferred statistical method.[24] A multivariate regression analysis was performed to determine the effect of complexity on these continuous outcomes. In all analyses, a p-value below .05 was considered to indicate a statistically significant difference. All analyses were conducted using IBM SPSS Statistics version 27.[25]

RESULTS

Baseline characteristics

Between July 2013 and April 2021, 90 patients with complex aortic aneurysms were treated. Figure 2 shows how many patients were treated each year. A steady increase occurred in the first four years. Table 1 shows the baseline characteristics of these patients: 74 (82%) were male and mean age was 73.6 years (SD=6.3). Columns 3-6 of Table 1 show the baseline characteristics of the three temporal groups. The groups were comparable on all variables, including age, gender, BMI, comorbidities, risk factors, and ASA-score. No statistical differences were detected between baseline characteristics.

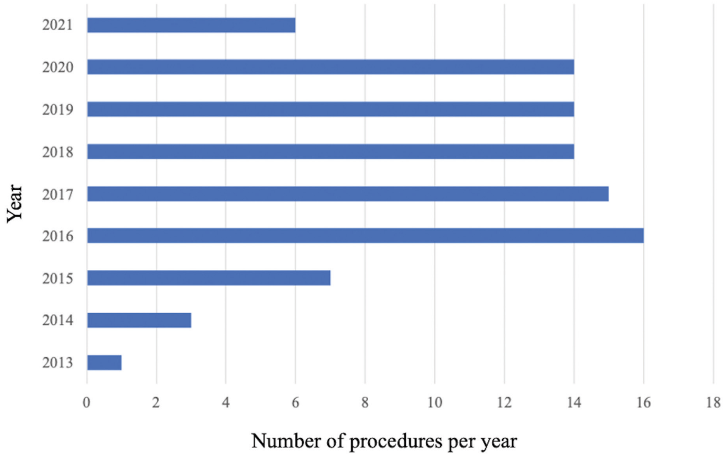


Figure 2: Number of complex EVAR procedures per year.

Qualitative assessment; factors influencing the learning curve

In 2017, after 46 procedures and four years of treatment, all ETT members were interviewed.[20] Factors were considered to be vital to the procedure if they were mentioned at least ten times by at least five different interviewees. They were divided into factors enabling relational embeddedness, cognitive embeddedness, and team learning. One factor enabling relational embedding was adequate *communication*. Communication should occur on a frequent basis, among all members of the ETT, and in formal as well as informal settings. In the preparatory phase, pre-case multidisciplinary briefings provided formal occasions of communication. During surgery, "thinking out loud" by the performing surgeons and interventional radiologists enabled involvement of all participating team members in the OR. In addition to communication during official meetings and in the OR, informal discussion and social gatherings provided occasions of valued interaction. Communication was supported by a culture of *mutual trust*; all team members felt free to openly share their opinions and raise concerns. This depended on the team environment, which was created over time.

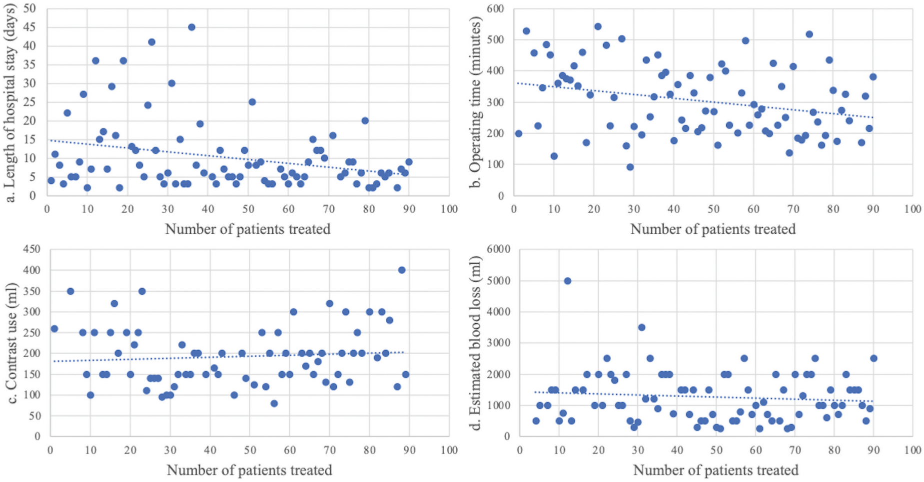
According to the interviewees, a shared understanding of different team roles was vital to successful team performance. This contributed to cognitive embedding. Differences in hierarchical positions and the line of command between team members were accepted by all team members. Clear *authoritative structures* had to be present and unquestioned, while at the same time maintaining mutual trust. Another contributing factor to cognitive embedding was a strong sense of *shared responsibility and collective goals*. This included attendance of all pre-case and postoperative meetings. It also encompassed a realization of the interdependence between team members. Due to the necessity of each team member's contribution, participants should be able to rely on each other, and therefore feel the obligation to enable the task execution of others. We found that the importance of this factor extended into the operating room (OR). During the procedure, it was expected that all conversations only concerned the treatment being performed and all members focused on their task, while being dedicated to the overall team performance. The feeling of responsibility exceeded planned working hours.

Three factors were identified to have contributed to team learning. Team members *shared their knowledge,* which meant that more information than strictly necessary to perform an assigned task was exchanged. Again, debriefing was important in this matter. In addition, acquired skills and experiences were shared for other team members to learn from, along with relevant developments in the different disciplines involved: *mutual learning*. Besides becoming familiar with the technical aspect of the procedures, team members also had to become acquainted with other members' way of work and preferences. Familiarity with each other's body language and specific preferences contributed to successful task performance and built *team capabilities*.

Quantitative assessment

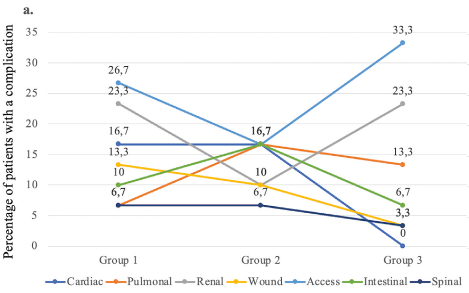
Figures 3a-d show the quantitative learning curves for blood loss, operating time, length of hospital stay, and volume of contrast. Specifics are depicted in Table 2. It shows a statistically significant decline in operating time (Time (minutes) = 361.1 – 1.235 x number of procedures, p=.010, CI: -2.17;-0.30) and length of hospital stay (Length of stay (days) = 14.7 – 0.102 x number of procedures, p=.008, CI:-0.18;-0.03). No statistically significant trend was detected for blood loss (Blood loss (milliliters) = 1433.7 – 3.394 x number of procedures, p=.345, CI:-10.50;3.71) or contrast use (Volume of contrast (milliliters) = 180.8 + 0.240 x number of procedures, p=.480, CI:-0.43;0.91). No changes in statistical significance occurred after correction for complexity level. The adjusted regression coefficients were -1.344 (CI: -2.25;-0.44, p=.004) for operating time, -5.665 (CI: -12.43;1.10, p=.100) for blood loss, 0.365 (CI: -0.33; 1.06, p=.300) for volume of contrast, and -0.106 (CI: -0.17;-0.04, p=.003) for length of stay.

Table 2 shows that there was no significant difference between the three temporal groups in 30-day mortality (1: 3%, 2: 10%, 3: 7%, p=.435), MAE's (1: 17%, 2: 30%, 3: 27%, p=.554), initial technical success of the procedure (1: 93%, 2: 90%, 3: 83%, p=.592), endoleak repair-free survival (1: 50%, 2: 33%, 3: 77%, p=.081), or reintervention-free survival for stent graft or aneurysm complications (1: 67%, 2: 73%, 3: 53%, p=.612). The number of patients discharged to a rehabilitation center did not significantly differ between the groups of experience (1: 20% vs. 2: 20% vs. 3: 13%, p=.964). The Poisson regression coefficients were 0.009 for 30-day mortality (p=0.572), 0.006 for MAE's (p=0.497), -0.002 for initial technical success (p=0.721), -0.011 for endoleak repair (p=0.257), -0.021 for other reinterventions (p=0.107), and -0.001 for discharge to a rehabilitation center (p=0.874). This indicates, on a log scale, no statistically significant effect of patient volume on these outcomes.



Figures 3a-d: Regression plots showing a statistically significant decline in (a) length of hospital stay (p=.008) and (b) operating time (p=.010). No significant trends were detected for (c) contrast use (p=.480) or (d) blood loss (p=.345). ml = milliliters

Figures 4a-b show the trends in postoperative complications per temporal group, presented by the type of complications (figure 4a) and by Clavien-Dindo score (figure 4b). It shows a significant decrease in the percentage of patients with cardiac complications in group 3 vs. group 2 and 1 (3: 0%, 2: 17%, and 1: 17%, p=.042). In addition, it shows an increase in the percentage of patients with access complications, but this ascending trend was not statistically significant (p=.322). There were no significant changes in the severity of complications.



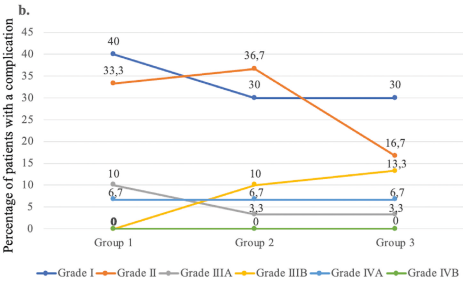


Figure 4a: Percentage of patients with one or more post-operative complications with a Clavien-Dindo score of I-IVB, presented per group of experience (n=30). The decline in cardiac complications was statistically significant (p=.042).
Figure 4b: Percentage of patients with one or more post-operative cardiac, renal, access, wound, pulmonal, intestinal, or spinal complications per group of experience, presented by Clavien-Dindo score. There were no statistically significant differences between groups.

There was a trend towards an increase in complexity over the years. Table 1 shows that the number of procedures with a complexity score of 3 is larger in group 3 compared to group 1 (n=18 vs. n=8), which was mainly caused by an increase in FEVAR procedures with 4 fenestrations (n=10 vs. n=3). However, this trend did not present a statistically significant difference in overall complexity scores between groups (p=.076). There was also a trend towards an increase in the number of fenestrations per procedure, mainly caused by an increase in procedures with 3 fenestrations and a scallop, and procedures with 4 fenestrations. This trend was not statistically significant (p=.060).

DISCUSSION

Qualitative analysis

According to our interview data, factors thought by the interviewees to have positively influenced the learning curve were: communication, mutual trust, a shared sense of responsibility and collective goals, clear authoritative structures, knowledge sharing, mutual learning, and team capabilities. When implementing new techniques in the future, several of these factors can be encouraged from the start, for example by organizing team meetings in which experiences are shared, and mutual learning is supported.

Figure 5 (supplementary material) shows a comparison between our factors of influence and corresponding literature factors.[6,7,26] The need for a shared sense of responsibility and collective goals resembles the "shared mental model" introduced by *Aveling et al.*: team members should be motivated, focused, and dedicated.[6] Our analysis complements this factor by adding that this attitude should extend into the OR. *Parker et al.* discusses surgical leadership, which our factor of clear authoritative structures partially encompasses.[27] A contributing factor revealed by our analysis, but not discussed in the literature concerning learning curves, is mutual learning. Experiences and relevant developments in the different disciplines should be shared with other team members, even if this strictly extends beyond the scope of their assigned tasks. A factor mentioned in the literature that we did not identify in our data, is performing "trials of a new routine".[7] This might be absent in our findings because additional techniques are introduced on a rolling basis in complex EVAR. Moreover, each procedure is adjusted to the specific configuration of the aneurysm that is being treated, which prevents complex EVAR from becoming routine surgery.

Quantitative analysis

Despite a trend of increased complexity, operating time declined, which indicates technical learning took place. An increase in complexity would be in line with existing literature that shows that with growing exposure, complex EVAR became technically more demanding.[28] Length of hospital stay, with a cluster of patients with a long length of stay in the earlier treatment stage (Figure 3a), significantly decreased as well.

Despite a slight trend of increased thirty-day mortality and major complications (mainly between groups 1 and 2), these results were not statistically significant, and adverse outcomes remained at comparable levels. In addition, the number of cardiac complications declined. Our 30-day mortality and MAE numbers can be compared to previous research with a higher number of patients, such as *Oderich et al.* (30-day mortality of1.8-8.2%, MAE in 32-36%, depending on complexity) and *Tran et al.* (30-day mortality of 8.6%, MAE in 21.1-23.5%, depending on complexity).[14-15]

A decrease in operating time was also present in the learning curves of *Mirza et al.* (fenestrated-branched combinations) and *Starnes et al.* (FEVAR).[17-18] In addition, *Mirza et al.* presented a decline in 30-day mortality and the incidence of MAE, although the incidence of MAE in our third group of experience (27%) resembles the incidence in the final group in *Mirza et al*. (29%). It should be noted that these studies described specific subgroups, whereas the current study included all types of complex EVAR. This impedes meaningful comparison of results.

Possible confounding factors

When interpreting a learning curve, confounders need to be taken into account. Procedural changes and adjustments in patient selection did occur during eight years of treatment. Although a change in patient characteristics was not identified, in our experience more complicated cases were taken on, based on combinations of case complexity and aneurysm configurations. Our complexity score was solely based on stent graft configuration, which does not include all aspects of a procedure's difficulty level. Factors that could be included for a more comprehensive complexity score are tortuosity, the way access was gained, and whether target vessel stenosis was present. Although consistency was aspired within the ETT, changes in team composition did occur over the years, as specified in the methods section. Another possible confounder is the fact that new innovations were introduced in the endovascular program, such as carbon dioxide flushing of thoracic stents to prevent cerebral air embolisms and branched and fenestrated arch-EVAR. The slight rise in access complications could be due to the introduction of percutaneous femoral access.

Strengths and limitations

The current study consecutively included all patients that underwent complex EVAR during eight years of treatment. Because treatment took place in a single center, inclusion was limited to 90 patients. This represents an unselected 'real world' complex EVAR population and provides insight in the outcome numbers of a medium-volume center. However, it does limit the extend of the analyses. If more patients were to be included, additional analyses could be performed, such as multivariate learning curve analysis corrected for confounding factors. With the current sample size, this could not be performed in a robust fashion. The temporal groups enabled us to determine whether learning took place. The regression plots depict the rate of learning and indicate that learning has not stopped. Although widely used and accepted, our methods only partially describe the shape of the underlying learning curve (Figure 1). Future research aims to establish a mathematically more rigorous approach. This would provide a more thorough comparison of different learning curves and could enable treatment teams to determine what stage of learning they are in.[4, 24]

Another challenge is the fact that the qualitative data were gathered inductively, without ex ante referencing the medical learning curve literature. Suggestions regarding the interaction between qualitative and quantitative results thus depend on our interpretation. In future research, quantitative and qualitative data should preferably be examined prospectively. This enables researchers to investigate whether findings in the quantitative curves are reflected in the interviews, and vice versa. However, this fundamentally contradicts the inductive approach we took, which has as a core strength that interviewees dictate which factors are most important.

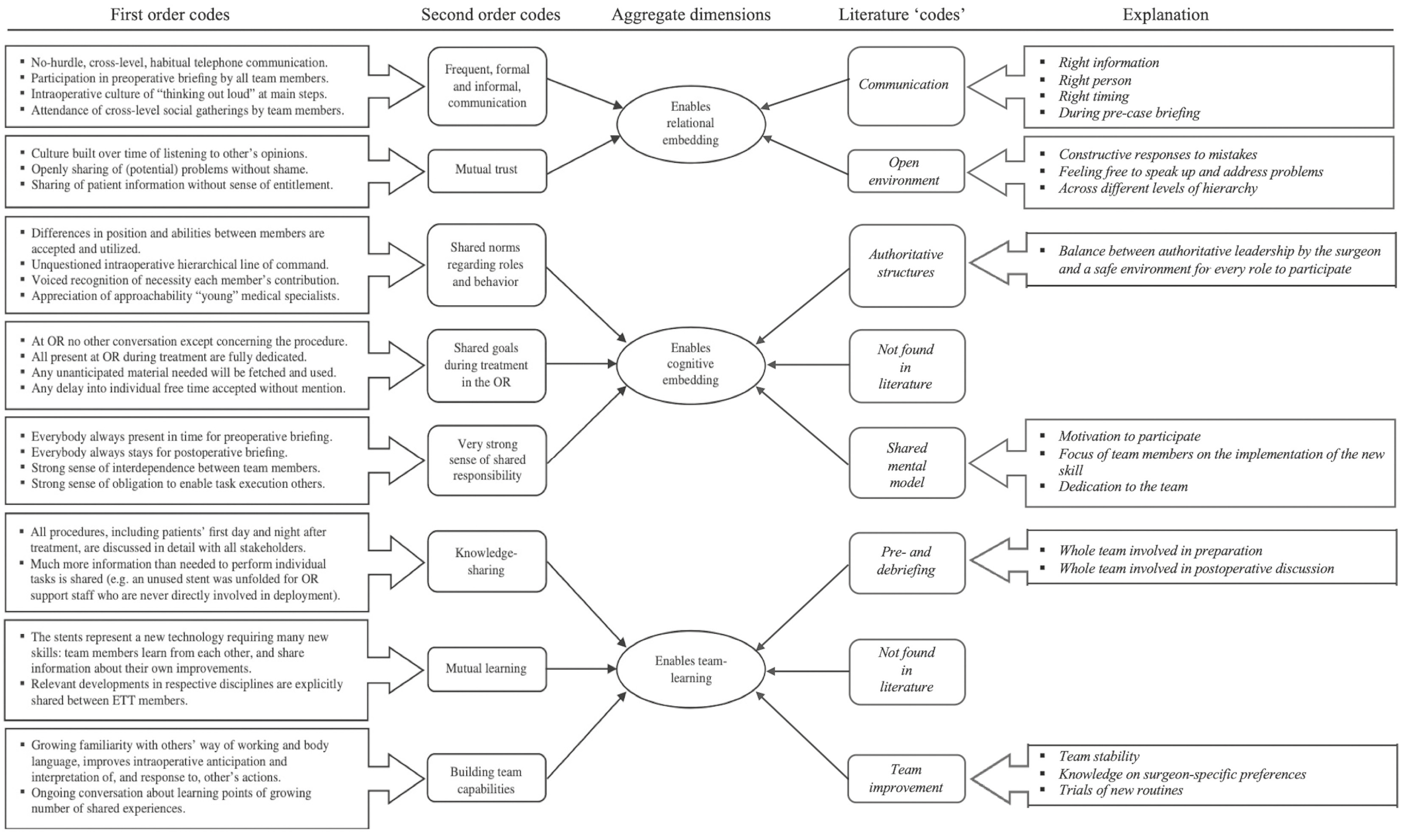
CONCLUSION

This study presented a quantitative as well as a qualitative analysis of the complex EVAR learning curve in a non-high-volume hospital. Despite a trend of increased complexity, operating time, length of hospital stay, and cardiac complications declined. Thirty-day mortality and MAE showed no statistically significant changes. We found that several learning curve factors that were previously identified in other fields, extend to the field of complex EVAR: adequate communication, a shared sense of responsibility, mutual trust, clear authoritative structures, and team capabilities. The factors mutual learning and shared goals during treatment in the OR were added by our research, and can aid in future implementation of new techniques. With complexity bound to increase, monitoring progress and striving for optimization of team learning will become even more relevant.

INTERIM SUMMARY

In this chapter, a learning curve analysis was presented regarding the implementation of complex EVAR in the Leiden University Medical Center, using the results of patients treated between July 2013 and April 2021 (n=90). A decrease in operating time and length of hospital stay implicate technical learning. In addition, qualitative factors experienced as a positive contributor to learning were presented. Most of these factors were recognized in literature regarding other fields. Mutual learning was added. Although the data did not support an increase in patient complexity in a statistically significant manner, the treatment team did experience such a change. This hypothesis will be further investigated in Part 2, describing changes in the treated complex aneurysm population with the introduction of complex EVAR.

TABLES AND SUPPLEMENTARY FIGURES



- No-hurdle, cross-level, habitual telephone communication.
- Participation in preoperative briefing by all team members.
- Intraoperative culture of "thinking out loud" at main steps.
- Attendance of cross-level social gatherings by team members.

- Culture built over time of listening to other's opinions.
- Openly sharing of (potential) problems without shame.
- Sharing of patient information without sense of entitlement.

- Differences in position and abilities between members are accepted and utilized.
- Unquestioned intraoperative hierarchical line of command.
- Voiced recognition of necessity each member's contribution.
- Appreciation of approachability "young" medical specialists.

- At OR no other conversation except concerning the procedure.
- All present at OR during treatment are fully dedicated.
- Any unanticipated material needed will be fetched and used.
- Any delay into individual free time accepted without mention.

- Everybody always present in time for preoperative briefing.
- Everybody always stays for postoperative briefing.
- Strong sense of interdependence between team members.
- Strong sense of obligation to enable task execution others.

- All procedures, including patients' first day and night after treatment, are discussed in detail with all stakeholders.
- Much more information than needed to perform individual tasks is shared (e.g. an unused stent was unfolded for OR support staff who are never directly involved in deployment).

- The stents represent a new technology requiring many new skills: team members learn from each other, and share information about their own improvements.
- Relevant developments in respective disciplines are explicitly shared between ETT members.

- Growing familiarity with others' way of working and body language, improves intraoperative anticipation and interpretation of, and response to, other's actions.
- Ongoing conversation about learning points of growing number of shared experiences.

- *Right information*
- *Right person*
- *Right timing*
- *During pre-case briefing*

- *Constructive responses to mistakes*
- *Feeling free to speak up and address problems*
- *Across different levels of hierarchy*

- *Balance between authoritative leadership by the surgeon and a safe environment for every role to participate*

- *Motivation to participate*
- *Focus of team members on the implementation of the new skill*
- *Dedication to the team*

- *Whole team involved in preparation*
- *Whole team involved in postoperative discussion*

- *Team stability*
- *Knowledge on surgeon-specific preferences*
- *Trials of new routines*

Figure 5: Factors influencing the learning curve identified in the interviews and corresponding factors deriving from literature (in cursive).[6-7, 20, 26]

Table 1: Patient characteristics

Variable (unit)	All patients (n=90)	Group 1 (n=30)	Group 2 (n=30)	Group 3 (n=30)	p-value*
Age (years), mean (SD)	73.6 (6)	72.8 (6)	73.2 (7)	74.9 (6)	.379
Male, n (%)	74 (82)	24 (80)	25 (83)	25 (83)	.927
BMI (kg/m^2), mean (SD)	26.6 (4)	26.4 (3)	27.1 (4)	26.1 (3)	.539
Aneurysm size (mm), mean (SD)	65.1 (11)	67.6 (15)	63.1 (7)	64.5 (9)	.255
Aneurysm configuration, n(%)					
Crawford 1	7 (8)	4 (13)	3 (10)	0	
Crawford 2	11 (12)	4 (13)	4 (13)	3 (10)	
Crawford 3	6 (7)	3 (10)	0	3 (10)	.078
Crawford 4	8 (9)	4 (13)	2 (7)	2 (7)	
Suprarenal	3 (3)	0	0	3 (10)	
Juxtarenal	52 (58)	15 (50)	18 (60)	19 (63)	
Aortic arch	3 (3)	0	3 (10)	0	
Procedure complexity, n (%)					
Level 1	12 (13)	7 (23)	3 (10)	2 (7)	
1 fenestration	2	2	0	0	
1 fenestration and scallop	3	2	1	0	
2 fenestrations and scallop	7	3	2	2	
Level 2	42 (47)	8 (27)	16 (53)	18 (60)	.076
3 fenestrations	9	2	5	2	
3 fenestrations and scallop	18	3	9	6	
4 fenestrations	15	3	2	10	
Level 3	29 (32)	13 (43)	7 (23)	9 (30)	
Level 4	7 (8)	2 (7)	4 (13)	1 (3)	
ASA-score ≥3, n (%)	54 (60)	15 (50)	18 (60)	21 (70)	.311
Comorbidities, n (%)					
MI/ACS	31 (34)	9 (30)	9 (30)	13 (43)	.490
AF or other cardiac comorbidities	35 (39)	15 (50)	11 (37)	9 (30)	.319
COPD	22 (24)	8 (27)	9 (30)	5 (17)	.554
Other pulmonary comorbidities	9 (10)	2 (7)	4 (13)	3 (10)	.905
eGFR <60 ml/min/1.73m2	38 (42)	16 (53)	8 (27)	14 (47)	.096
CVA/TIA	23 (26)	8 (27)	7 (23)	8 (27)	1.000
Diabetes Mellitus type 2	11 (12)	6 (20)	3 (10)	2 (7)	.366
Risk factors, n (%)					
Currently smoking	26 (29)	6 (20)	12 (40)	8 (27)	.406
Hypercholesterolemia	29 (32)	9 (30)	10 (33)	10 (33)	1.000
Hypertension	65 (72)	22 (73)	21 (70)	22 (73)	1.000
Low tolerance of exercise (MET 1-4), n (%)	13 (14)	5 (17)	5 (17)	3 (10)	.919

Abbreviations: BMI = Body Mass Index, ASA = American Society of Anesthesiology, MI/ASC = myocardial infarction/acute coronary syndrome, AF = atrial fibrillation, COPD = chronic obstructive pulmonary disease, eGFR = estimated glomerular filtration rate, CVA/TIA = cerebral vascular accident/transient ischemic attack, MET = metabolic equivalent of task

*p-value of comparison between groups of experience

Complexity level 3: branched-EVAR, level 4: branched-fenestrated EVAR combinations, arch EVAR, and emergency cases.

Table 2: Outcome comparison between groups

Outcome	Group 1 (n=30)	Group 2 (n=30)	Group 3 (n=30)	p-value*
Continuous, median (Q1-Q3)				
Operating time (minutes)	360 (222-458)	304 (219-385)	245 (191-333)	.010
Blood loss (ml)	1000 (563-1950)	1200 (600-2000)	1000 (675-1625)	.345
Length of stay (days)	9 (5-20)	6 (3-11)	6 (5-9)	.008
Contrast use (ml)	150 (140-250)	150 (140-200)	200 (150-290)	.480
Fluoroscopy time (minutes)	69 (42-88)	86 (65-124)	82 (63-104)	†
Dichotomous, n (%)				**p-value‡**
30-day mortality	1 (3)	3 (10)	2 (7)	.435
Major Adverse Events	5 (17)	9 (30)	8 (27)	.554
Freedom from endoleak repair	15 (50)	10 (33)	23 (77)	.081
Freedom from reinterventions	20 (67)	22 (73)	16 (53)	.612
Initial technical success	28 (93)	27 (90)	25 (83)	.592
Discharge to a rehabilitation center	6 (20)	6 (20)	4 (13)	.964

*p-value of the regression analyses, †fluoroscopy time was not included in the regression analysis due to 22 missing values in group 1 (n=8), ‡p-value of the comparison between groups of experience. ml = milliliters

Appendix A available online via:

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