Learning the Learning Curve of Robotic Coronary Artery Bypass

Saqib Masroor[1] and Abdullah Nasif[2]

[1]University of Toledo Medical Center
[2]The University of Toledo Medical Center

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Manuscript: *The Learning Curve of Robotic Coronary Arterial Bypass Surgery: A Report from The STS Database* ***Disclosure*** : *None* ***Word Count*** : *1229*

Learning the learning curve of robotically assisted coronary artery bypass grafting is important for the advancement of this technique and the improvement in patient outcomes. There have been many reports of single surgeon learning curves.[1, 2] But one can argue that they depict one surgeon's journey, depicting his or her dedication to the field and making generalization to other surgeons difficult, if not impossible.

In this issue of the Journal of Cardiac Surgery, Patrick et al, report on their investigation of the Society of Thoracic Surgeons (STS) database for Robotically Assisted Coronary Artery Bypass (RA-CABG) procedures and the beginner surgeon's learning curve.[3]Between 2014 and 2018, a total of 1195 RA-CABGs were performed by 114 surgeons, with 74 surgeons performing <5 procedures and only 9 surgeons performing >25 procedures. The median number of cases performed was 2. The patient population was younger and relatively lower risk. The cases included single-vessel as well as multi-vessel Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) in addition to Totally Endoscopic Coronary Artery Bypass (TECAB) and there is no subgroup analysis reported for the different procedures. The authors conclude that the learning curve for procedural success is overcome by the 10^{th} case, even though the curve for reoperation is still steep by the 25^{th} case. Operative mortality however was similar in the two groups. The authors conclude that surgeon experience is an independent predictor of RA-CABG procedural success and that the learning curve consistently flattens after the surgeon's 10^{th} case. We agree with the first but not the second conclusion. Here is why!

In 2013, Prof Mohr's group in Leipzig reported on the learning curve of minimally invasive mitral valve surgery at their institution over a 17-year period involving 3895 operations performed by 17 surgeons performing their first minimally invasive procedure, using the sequential probability cumulative sum (CUSUM) statistical technique.[4] Learning curves were then determined for total operation times, aortic cross-clamp times, and primary outcomes. The mean number of operations per surgeon was 189. The authors reported a learning curve of between 75-125 procedures, with evidence that surgeons needed to perform more than 1 cases per week to maintain good results. Importantly however, patient mortality was not compromised because of the learning curve.

To assess the learning curve involved in performing a task, it is important that both the task and the tools needed for the task remain constant. The above publication fulfills both of these criteria. 82 percent of cases were mitral valve repair and 18 percent were mitral valve replacement. The surgical technique and technology used was nearly identical and robotic mitral valve procedures were excluded. The institution had the same leadership over the period, allowing for a very stable work environment as well as a consistent approach including case selection, operative technique etc. As much as possible, every variable was the same, except the variable under investigation-'the beginner surgeon'. The same group had reported the learning curve for MIDCAB to be between 50-100 cases for 8 surgeons at their institution.[5]

Now let us analyze the report from Patrick et al.[3] In this report, the task is not the same and neither are the tools. Single vessel RA-MIDCAB is a less challenging procedure than multi-vessel RA-MIDCAB, with its associated variety of conduit procedures (such as bilateral Internal Mammary Artery (IMA) grafting, Radial Artery T-grafting from Left Internal Mammary Artery (LIMA) to the lateral wall, or aortocoronary Saphenous Vein bypass procedures). TECAB is a totally different beast altogether. Grouping all of them in one learning curve is not a valid assumption. As far as the tools/technique is concerned, some patients had beating heart surgery while others had arrested heart procedures, exposing the Left Anterior Descending Artery (LAD) in MIDCAB is a different task than exposing the lateral wall targets or the stabilizing the LAD endoscopically. Each one of those steps/techniques have their own learning curves.

Another shortcoming of this study is the relatively small experience of most of the surgeons in the study. 74 out of the 114 surgeons in the study had $<$ 5-case experience. Moreover, it is not clear what the experience of the surgeons was before embarking on this technique. In the Leipzig study, surgeons with less than 5 cases were excluded from analysis and the 17 surgeons had an experience of at least 40 mitral valve procedures via sternotomy before using the minimally invasive approach.[1]

Finally, the definition of procedural success can be debated. It was defined as an inverse composite of the three primary outcomes - conversion, re-operation, and major morbidity/mortality. While this "procedural success" composite showed a flattening of the learning curve at 10 cases, the reoperation rate was still improving even after 25 cases. A chain is only as strong as the weakest link. If the reoperation rate is still improving after 25 cases, procedural success cannot be declared to have been mastered at 10 cases. Further analysis of the groups of surgeons with $<$ 10 or $>$ 10 cases reveals the procedural success to be 72.9% and 85.3% respectively. 15% failure of procedural success would not be consistent with overcoming the learning curve. We assume that surgeons must strive to continue improving the procedural success until it reaches well into the 90's percent rate, which would be required for a successful RA-CABG program.

The major advantage of a large clinical database such as the Adult Cardiac Surgery Database (ACSD) is the minimization of bias due to its large number of observations. However, for rare procedures such as RA-CABG, that advantage is lost. In fact, with such a small number of observations over such a diverse set of procedures and institutions, ACSD data is not granular enough to explore an individual surgeon's learning curve because there is no control for numerous other variables at the departmental and institutional level that are not tracked by ACSD. A high-volume center in a steady-state clinical work environment controls for most variables that influence clinical outcomes. The only variable that changes, is the beginner surgeon, and the data thus obtained is more likely to represent the true "learning curve" of the procedure.

It is important to have realistic expectations from new technology. Many beginners would embark on this journey, hoping to master the learning curve in 10 cases. And when that expectation is not fulfilled in real life, they might give up altogether on this very useful approach. The number and frequency of operations are important, not just for the surgeons, but even more so, for the rest of the operating room team including anesthesiologists and patient-side assistants. The whole team can be feel discouraged if they continue to have a learning curve beyond 10 or even 20 cases.

In conclusion, querying the Adult Cardiac Surgery Database of STS may not be the best way of learning the learning curve of a rare procedure(s). There is a concern that setting an unrealistically optimistic expectation of 10 operative cases to master the learning curve of RA-CABG may be detrimental to the progress of this approach. A high-volume centers' experience with multiple beginner surgeons may be a better representative of the learning curve of RA-CABG and that study has not yet been done. But based on the learning curves of other similar procedures and our own experience, it is our opinion that the learning curve of RA-CABG would be somewhere between 50 and 100 cases for MIDCAB and another 50-100 for TECAB.

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