The Pace of Transradial Procedural Learning

J. Dawn Abbott, MD

The uptake of transradial coronary intervention (TRI) in the United States has been slow relative to other countries. Fortunately, adoption appears to be on the rise, with a steady increase in the overall percentage of TRI since 2009. Learning curves, similar to adoption curves, are generally not linear. When learning or proficiency is plotted against time, progress may be slow at first, and then there is a period of rapid change followed by an apparent plateau. Although small improvements are made continuously after the plateau, the progress may not be visible until there is an extended period of observation. Surprisingly, for many different motor or procedural skills, the shape of the learning curve is similar, and there is less variance in performance as experience increases.

Although numerous studies have examined the benefits of TRI on outcomes, there has been little formal study of requirements to become a proficient TRI operator. Several factors may influence the slope of the TRI learning curve, including the cumulative interventional experience of the operator and availability of resources for training.

In this issue of *Circulation*, Hess and colleagues elucidate the learning curve for TRI in operators adopting the transradial approach in the United States from 2009 to 2012. With the use of data from 54,561 procedures in the National Cardiovascular Data Registry performed by 942 operators at 704 sites, measures of technical proficiency including fluoroscopy time, contrast volume, and procedural success were assessed according to TRI case volume. In hospital outcomes including mortality, vascular complications and bleeding were also assessed. Operators were considered new transradial operators and were included in the analysis if they had no TRI procedures for a 6-month blanking period during which time they performed ≥1 femoral percutaneous coronary intervention (PCI).

Because of inability to model the learning curve with a case volume of <15, operators in this volume range were excluded; remarkably, this accounted for 1862 operators or 66.4% of the new TRI operators. A possible explanation is that the majority of these operators initiated TRI at the end of the study period. Other possibilities are that some operators abandoned the transradial approach after early experience or reserved TRI for selected cases. Nonetheless, the beginning of the learning curve was estimated with the use of the early cases from the operators included in the study. On the high end of the volume spectrum, operators performing >200 TRI were also censored such that only data from the first 200 cases were included in the analysis. Fewer than 20 operators were in this high-volume category. The results therefore provide excellent discrimination of skills with increasing TRI experience up to 200 cases but cannot inform us about the extended learning curve in more experienced operators. The analysis was adjusted for femoral interventional volume during the study period before the TRI procedure being modeled but not cumulative PCI experience. Additionally, subgroups identified to be high risk for TRI procedural failure, including women and patients aged ≥75 years, were examined.

With respect to patient and procedural characteristics, 29.7% were female, 7.0% had PCI for ST-segment elevation myocardial infarction, and nearly 90% of the PCIs were performed ad hoc, suggesting that operators performing transradial diagnostic catheterization were comfortable with proceeding immediately to intervention. As TRI volume increased, median fluoroscopy times and contrast use significantly decreased. These improvements in proficiency were present even though operators were more likely to select more complex and high-risk cases over time. The learning curve for TRI was steepest for operators performing 30 to 50 cases, and then further gains were present but less evident in operators performing >50 TRIs. Similar curves were observed for women and older patients.

The term steep learning curve has been used to describe difficult experiences; however, in this study and in most contexts, learning is fastest on the steepest part of the learning curve. In this study, procedural success was high, and mortality and complication rates were low and independent of TRI volume, suggesting that “learning” the procedure in the clinical setting is safe when performed by practicing operators. The study, however, did not assess the cumulative PCI volume of the operators, and there is a possibility that more experienced operators were adopting TRI in the United States during the time period examined. In addition, a major caveat with these findings is that the rate of access site crossover (transradial failure) is unknown because these data were not collected in National Cardiovascular Data Registry CathPCI Registry version 4. Although it is probably uncommon, one could imagine a scenario in which TRI is attempted and, because of an intra-procedural complication, transfemoral access is used to complete the PCI and the procedure may be coded as transfemoral. Prior studies suggest that the transradial failure rate is 1% to 10% depending on operator experience and rarely occurs after guide catheter placement.

The present study adds to the growing literature on the learning curve with TRI and has the largest number of

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operators and TR procedures to date (Table). 5–11 Multiple measures have been used to assess proficiency, and the trends are consistent despite study differences. For novice operators, only 25 to 80 cases are needed, and the learning curve plateaus for simple measures of technical proficiency. Procedural learning continues, however, and the study by Burzotta et al7 demonstrates that even expert TR operators can be differentiated on the basis of volume. In >10000 TR procedures performed by high-volume operators (>250 coronary diagnostic or interventional cases per year), those who performed >90% TR (“dedicated radialists”) were compared with those who performed >60% TR (“standard radialists”). Over the period of observation, transradial failure significantly decreased in both groups but was consistently lower in dedicated radialists. Although many studies, including the present analysis, suggest that mortality is not related to TR experience, that may be due to the fact that few studies have included patients with high enough clinical risk or a sufficient number of expert TR operators.12,13

On a broader level, the study informs us about the procedural experience of >900 operators in the United States. The median total number of TRI procedures performed by individual operators was low at 40, and only 148 operators performed >100 cases. The total number of transfemoral PCI cases during the same period was not reported; therefore, the percentage of TRI and total PCI volume are unknown. Some experts have advocated for procedural immersion, the practice of consecutive rather than selective use of TRI as a strategy to accelerate TRI adoption and learning curves. Certainly, some data support the notion that dedicated radialists perform the procedure more safely and efficiently than operators who use the approach on a selective basis.7 This study does not provide the relevant data to compare these learning strategies, but on the basis of the average number of PCI cases per year by US operators, one can estimate that fewer than half are done transradially during the learning phase. In the absence of immersion, it may take several years for a low-volume operator to gain TRI proficiency and to be comfortable treating high-risk patients, who have the most to benefit. A single-center study demonstrated that the implementation of a preferred TR approach in a transfemoral laboratory is feasible. With a commitment from the catheterization laboratory and operators, the TR approach went from <1% to 78% over a 15-month period. The crossover rate was 9.1%, with a suggestion of improvement in the last 3 months.14

The most recent document on clinical competence in coronary intervention recommends a minimum of 50 PCI procedures per year to maintain competency but does not specifically address vascular access.15 The European consensus statement recommends 80 transradial coronary procedures annually, both diagnostic and interventional, to maintain proficiency.16 The next step in changing the transfemoral culture in the United States is to target the cardiology training curriculum and ensure that the next generation of operators has the cognitive knowledge and procedural skills for TR catheterization. The Core Cardiology Training Symposium guidelines published in 2008 include performance of vascular access from the femoral, radial, or brachial route as a technical skill requirement but do not define procedural numbers.17 The Core Cardiology Training Symposium guidelines are currently

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**Table.** Studies Evaluating the Learning Curve in Transradial Cardiac Catheterization

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Period</th>
<th>Trial Design</th>
<th>Operator Transradial Experience*</th>
<th>Measures of Transradial Proficiency</th>
<th>Learning Curve Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hess5</td>
<td>2009–2012</td>
<td>Multicenter; United States; 54561 TRIs</td>
<td>Novice (0% transradial)</td>
<td>↓ Fluoroscopy time</td>
<td>30–50 cases</td>
</tr>
<tr>
<td>Burzotta7</td>
<td>2005–2010</td>
<td>Single center; Italy; 10676 transradial catheterizations/ TRIs</td>
<td>Expert (standard &gt;60% transradial, dedicated &gt;90% transradial)</td>
<td>↓ Transradial failure</td>
<td>No plateau</td>
</tr>
<tr>
<td>Kasasbeh9</td>
<td>2009–2011</td>
<td>Single center; United States; 1112 transradial catheterizations/ TRIs</td>
<td>Novice (&lt;12% transradial)</td>
<td>↓ Fluoroscopy time</td>
<td>25–75 cases</td>
</tr>
<tr>
<td>Carrillo6</td>
<td>2002–2009</td>
<td>Single center; Spain; 8463 transradial catheterizations</td>
<td>Not reported (43.6% transradial prevalence in laboratory)</td>
<td>↓ Transradial failure</td>
<td>Plateau ≈90% transradial prevalence in laboratory</td>
</tr>
<tr>
<td>Looi10</td>
<td>2008</td>
<td>Single center; New Zealand; 318 transradial catheterizations</td>
<td>Novice (not reported)</td>
<td>↓ Fluoroscopy time</td>
<td>&gt;36 cases</td>
</tr>
<tr>
<td>Ball8</td>
<td>1998–2008</td>
<td>Single center; Canada; 1672 transradial catheterizations</td>
<td>Novice (0% transradial)</td>
<td>↓ Transradial failure</td>
<td>&gt;50 cases</td>
</tr>
<tr>
<td>Spaulding11</td>
<td>1994–1995</td>
<td>Single center; France; 415 transradial catheterizations</td>
<td>Not reported</td>
<td>↓ Transradial failure</td>
<td>&gt;80 cases</td>
</tr>
</tbody>
</table>

TRI indicates transradial intervention.

*At the start of the study period.
being revised, but it is unclear whether more specific TR training recommendation will be included in the document. For interventional fellows (level 3), cumulative fellowship experience of 60 TR diagnostic procedures and 50 TRI is a reasonable goal, comprising 20% of the procedural requirement. The content of a transradial curriculum has also been proposed.18 Single-center studies have examined integrating the transradial approach into cardiology training programs. Although the learning curve is more rapid for transfemoral procedures, fellows can safely perform TR procedures with low complication and transradial failure rates.19 The potential also exists to use mentored simulation training to improve transradial skills. A pilot study showed that skills learned through simulation are transferable to live procedures and are most beneficial for the least proficient operators.20

The present study suggests that interventional cardiologists can rapidly incorporate new skills into their armamentarium. Widespread adoption of techniques that improve patient outcomes, including TRI, therefore is inevitable, and as a profession we should set standards for training and maintenance of competency.

Disclosures
None.

References
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