The Pace of Transradial Procedural Learning

Running title: Abbott; Transradial Procedural Learning

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The uptake of transradial coronary intervention (TRI) in the United States (U.S.) 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 continuously made 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. While there are numerous studies looking at the benefits of TRI on outcomes, there has been very little formal study of what it takes 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 the U.S. from 2009 to 2012. Using data from 54,561 procedures in the National Cardiovascular Data Registry (NCDR) 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 included in the analysis if they had no TRI procedures for a 6 month blanking period during which time they performed one or more femoral percutaneous coronary intervention (PCI).

Due to the inability to model the learning curve with a case volume of less than 15,
operators in this volume range were excluded; remarkably this accounted for 1,862 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 reserve TRI for selected cases. Nonetheless, the beginning of the learning curve was estimated using the early cases from the operators included in the study. On the high end of the volume spectrum, operators performing over 200 TRI were also censored such that only data from the first 200 cases were included in the analysis. Less 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 prior to the TRI procedure being modeled; but not cumulative PCI experience. Additionally, subgroups identified to be high risk for TRI procedural failure including females and patient age 75 or older were examined.6

With respect to patient and procedural characteristics, 29.7% were female, 7.0% had PCI for STEMI, and nearly 90% of the PCI was performed ad hoc, suggesting that operators performing transradial diagnostic catheterization were comfortable 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 with >50 TRI. Similar curves were observed for the females 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 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 U.S. during the time period examined. In addition, a major caveat with these findings is that the rate of access site cross over (transradial failure) is unknown since these data were not collected in NCDR CathPCI Registry version 4. Although probably uncommon, one could imagine a scenario where TRI is attempted and due to 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.6, 7

The current study adds to the growing literature on the learning curve with TRI and has the largest number of operators and TR procedures to date (Table 1).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 al5 demonstrates that even expert TR operators can be differentiated based on volume. In over 10,000 TR procedures performed by high volume operators (>250 coronary diagnostic or interventional cases per year), those that performed >90% TR, “dedicated radialists”, were compared to those that 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 current 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 over 900 operators in the U.S. The median total number of TRI procedures performed by individual operators was low at 40, and only 148 operators performed over 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 is 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 there is data to support the notion that “dedicated” radialists perform the procedure more safely and efficiently than operators that use the approach on a selective basis.7 This study does not provide the relevant data to compare these learning strategies, but based on the average number of PCI cases per year by U.S. operators one can estimate that less than half are done transradially during the learning phase. In the absence of immersion it may take several years for a low volume operators gain TRI proficiency and 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 into a transfemoral lab 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 cross over rate was 9.1% with a suggestion of improvement in the last three 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, diagnostic and interventional, to maintain proficiency.16 The next
step in changing the transfemoral culture in the U.S. is to target the cardiology training
 curriculum and assure the next generation of operators has the cognitive knowledge and
 procedural skills for TR catheterization. The Core Cardiology Training Symposium (COCATS)
 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
 COCATS are currently being revised, but it is unclear if more specific TR training
 recommendation will be included in the document. For interventional fellows (Level 3),
 cumulative fellowship experience of 60 TR diagnostic and 50 TRI is a reasonable goal;
 comprising 20% of the procedural requirement. The content of a transradial curriculum have also
 been proposed.18 Single center studies have shown the ability to integrate 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 There is also the potential to use mentored simulation training to
 improve transradial skills. A pilot study showed that skills learned through simulation are
 transferable to live procedures and 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 are inevitable and as a profession we should set standards for
 training and maintenance of competency.

 **Conflict of Interest Disclosures.** None.

 **References:**

    M, Mann T. Transradial approach for coronary angiography and interventions: results of the first


Table 1. 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 TR experience*</th>
<th>Measures of TR proficiency</th>
<th>Learning curve estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hess^5</td>
<td>2009-2012</td>
<td>Multicenter</td>
<td>Novice (0% TR)</td>
<td>↓ Fluoroscopy time</td>
<td>30-50 cases</td>
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<td></td>
<td></td>
<td>U.S.</td>
<td></td>
<td>↓ Contrast volume</td>
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<td></td>
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<td>54, 561 TRI</td>
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<td>↑ Procedural success</td>
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<tr>
<td>Burzotta^7</td>
<td>2005-2010</td>
<td>Single center</td>
<td>Expert (standard &gt;60% TR,</td>
<td>↓ Transradial failure</td>
<td>No plateau</td>
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<td></td>
<td></td>
<td>Italy</td>
<td>dedicated &gt;90% TR)</td>
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<td></td>
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<td>10,676 TR cath/TRI</td>
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<tr>
<td>Kasasbeh^9</td>
<td>2009-2011</td>
<td>Single center</td>
<td>Novice (&lt;12% TR)</td>
<td>↓ Fluoroscopy time</td>
<td>25-75 cases</td>
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<td>U.S.</td>
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<td>↓ Procedure time</td>
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<tr>
<td>Carrillo^6</td>
<td>2002-2009</td>
<td>Single center</td>
<td>Not reported (43.6% TR</td>
<td>↓ Transradial failure</td>
<td>Plateau ~90% TR</td>
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<td>Spain</td>
<td>prevalence in lab)</td>
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<td>prevalence in lab</td>
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<td>8,463 TR cath</td>
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<tr>
<td>Looi^10</td>
<td>2008</td>
<td>Single center</td>
<td>Novice (Not reported)</td>
<td>↓ Fluoroscopy time</td>
<td>&gt;36 cases</td>
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<td>New Zealand</td>
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<td>↓ Procedure time</td>
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<td></td>
<td>318 TR cath</td>
<td></td>
<td>↔ Contrast volume</td>
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<tr>
<td>Ball^8</td>
<td>1998-2008</td>
<td>Single center</td>
<td>Novice (0% TR)</td>
<td>↓ Transradial failure</td>
<td>&gt;50 cases</td>
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<td>Canada</td>
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<td>↓ Fluoroscopy time</td>
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<td>1,672 TR cath</td>
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<td>↓ Contrast volume</td>
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<tr>
<td>Spaulding^11</td>
<td>1994-1995</td>
<td>Single center</td>
<td>Not reported</td>
<td>↓ Transradial failure</td>
<td>&gt;80 cases</td>
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<td>France</td>
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<td>↓ Procedure time</td>
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<td>415 TR cath</td>
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TR- transradial, TRI- transradial intervention. *At the start of the study period
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