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The Value of Transradial: Impact on Patient Satisfaction and Healthcare Economics

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INTRODUCTION

Transradial access (TRA) for diagnostic coronary angiography and percutaneous coronary intervention (PCI) has been used in clinical practice for over 25 years (1,2). Early techniques for coronary angiography via the Sones technique utilized brachial artery cutdown access and required specialized training for proficiency, but development of transfemoral access (TFA) using the Seldinger technique and preformed specialized catheters proved more operator-friendly and led to widespread adoption of TFA as the mainstay for both diagnostic and PCI access for many years (3-7). In a National Cardiovascular Data Registry (NCDR) analysis of over 600 procedural centers, radial access accounted for only 1.32% of total PCI procedures from 2004 to 2007 (8). Since then, multiple studies have demonstrated various benefits of TRA over TFA, notably less bleeding, vascular access complications, and cardiovascular events (9-13). In recent years, there has been a surge in the adoption of TRA for PCI (14-16). In an updated NCDR analysis examining radial utilization, while TRA was employed in only 1.2% of cases at the beginning of 2007, utilization increased to 16.1% of cases by the end of 2012 (15). This trend has continued, and according to NCDR CathPCI registry institutional report data for 2019, radial access utilization is approaching 40% (16).

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Due to mounting data emphasizing the tolerability, safety, and cost effectiveness of TRA, there has been growing support of a “radial first strategy” (17, 18). In this review, we discuss the advantages of TRA for patient satisfaction, patient safety, and the economic impact on hospitals and the healthcare system.

IMPACT ON PATIENT SATISFACTION

Multiple randomized clinical trials (RCTs) comparing radial versus femoral access for angiography or PCI have shown consistent patient preference for radial over femoral access (10, 13, 19, 20). In the RIVAL trial, which randomized more than 7,000 patients, greater than 70% of those surveyed indicated a preference for radial over femoral access for their next procedure (HR 8.99, 95% CI 7.86-10.28; $p < 0.0001$) (10). In SAFE-PCI, women undergoing radial access for diagnostic angiography or PCI were more likely to prefer the same access route for their next procedure than women who underwent femoral access (77.2% vs 26.8%; $p < 0.0001$), though assessments with validated instruments showed no measurable difference in quality of life in radial versus femoral groups (13, 21). For patients who had undergone both TRA and TFA in the CARAFE study, 58% preferred TRA versus 21% preferred TFA and 21% had no preference (19). Cooper et al conducted another randomized trial involving 200 patients that also showed the vast majority of patients strongly preferred radial access (20). Specifically, patients rated radial access as being more comfortable than femoral access, and patients undergoing femoral access reported more associated back pain and difficulty walking (19, 20). Survey data investigating patient preference related to vascular access during cardiac catheterization showed that decreased risk of major bleeding was the top priority for satisfaction. This was followed by desires for decreased length of stay (LOS) and maximized post-procedural mobilization (22).

PATIENT SAFETY AND BLEEDING RISK

In randomized trials, TRA has demonstrated lower rates of bleeding, vascular access site complications (VASCs), and composite outcomes of Major Adverse Cardiovascular Events (MACE) and Net Adverse Clinical Events (NACE) (9-13). In particular, data show safety benefits in the setting of acute coronary syndrome (ACS), when patients are at risk for bleeding complications related to receiving anticoagulation and antiplatelet agents. In targeted analyses of populations at high risk for procedural complications, including women, the elderly, and severely obese, radial access was shown to improve clinical outcomes (13, 23-25).

In the MATRIX trial, which randomized 8,404 patients with ACS to radial or femoral access, investigators observed lower rates of MACE in the TRA group (8.8% vs 10.3%; RR 0.85, 95% CI 0.74-0.99; $p = 0.0307$), though this was not a statistically significant finding based on a prespecified α of 0.025. There were also reduced rates of NACE favoring TRA (9.8% vs 11.7%; RR 0.83, 95% CI 0.73-0.96; $p = 0.0092$). In the TRA group, there were decreased bleeding rates when taking all major and minor bleeding indices into account (8.4% vs 14.4%; RR 0.55, 95% CI 0.48-0.63; $p < 0.0001$). In the TFA group, there were significantly higher access site-related BARC major bleeding, bleeding requiring blood transfusion, and VASC requiring surgical intervention (9).

Comparatively, the RIVAL trial randomized 7,021 patients with ACS to radial or femoral access and found no difference in the primary outcome of composite all-cause mortality, myocardial infarction (MI), stroke, or non-CABG bleeding at 30 days (3.7% vs 4.0%; HR 0.92, 95% CI 0.72-1.17; $p = 0.5$). There was also no difference between the groups in the individual outcomes of death, MI, or stroke. There were significantly lower rates of VASCs in patients undergoing radial compared to femoral intervention (1.4% vs 3.7%, $p < 0.0001$). Though there was no statistical difference in primary safety endpoints of non-CABG TIMI major bleeding, CABG-related bleeding, non-CABG-related blood transfusions, or all blood transfusions between TRA versus TFA, a post-hoc exploratory outcome analysis showed TRA was associated with significantly decreased AQUIITY major bleeding (defined as non-CABG major bleeding, large hematoma, or pseudoaneurysm requiring repair) when compared to TFA (1.9% vs 4.5%, $p < 0.0001$) (10).

In the RIFLE-STEACS trial, 1,001 patients with ST-elevation ACS, including those with cardiogenic shock and failed thrombolysis, were randomized to TRA versus TFA for intervention by experienced radial operators (those using radial access in more than 50% of cases). There was a significant reduction in the primary outcome of NACE – defined as the composite of cardiac death, stroke, MI, target lesion revascularization, and bleeding – in the TRA versus TFA group (13.6% vs 21.0%, $p = 0.003$). The radial arm showed significantly lower rates of MACE and cardiac death, implying a mortality benefit in ACS patients. Bleeding complications were also lower in the TRA versus TFA arm with hemoglobin drop ≥ 3 g/dL (6.0% vs 9.8%, $p = 0.036$) and bleeding requiring blood transfusion (1.0% vs 3.2%, $p = 0.025$). Access site related bleeding was 2.6% in the radial group versus 6.8% in the femoral group ($p = 0.002$). Overall non-CABG associated bleeding rate was 10% (7.8% in TRA vs 12.2% in TFA, $p = 0.026$). Investigators noted that considerable overall bleeding rates may have been partially explained by use of glycoprotein IIb/IIIa in 69% of these patients, which was not uncommon at the time of trial conduct. There was no difference between TRA and TFA groups for the use of these agents, implying that transradial access reduces bleeding when these agents are used (11).

In a similar setting of ST-elevation ACS, 707 patients were randomized to radial versus femoral intervention by experienced operators across four high-volume centers in the STEMI-RADIAL trial. Operators were trained in femoral approach but practiced in high-volume radial centers (centers with $>80\%$ radial cases). The TRA group compared with the TFA group demonstrated a significant reduction in the primary outcome of major bleeding or VASCs at 30 days (1.4% vs 7.2%, $p = 0.0001$). There was a significant reduction in NACE defined as composite of death, MI, stroke and major bleeding/vascular complications with TRA versus TFA. This reduction was primarily driven by decreased bleeding, as there was no statistical difference in MACE, MI, stroke, or death. With follow up at 30 days and 6 months, there was significantly less major bleeding in the radial group (1.4% vs 7.2%, $p = 0.0001$), even when vascular closure devices were used in 38% of femoral cases (12). Authors noted that a subgroup analysis of the femoral group showed no significant difference in bleeding or VASCs in those who did versus did not receive vascular closure. Overall, vascular complication rates were low at 0.6%, and there was no significant difference between radial and femoral groups (12).

SAFE-PCI, a registry-based randomized trial evaluating the effect of TRA versus TFA on outcomes in women undergoing PCI, enrolled 1,787 women referred for urgent or elective PCI or diagnostic catheterization with possible subsequent PCI. Patients having ST-elevation ACS were excluded. Of note, women have smaller radial arteries on average and are a population at higher risk of catheter-related complications. Radial access resulted in a statistically significant 70% reduction in the primary composite endpoint of bleeding or VASCs requiring intervention in patients undergoing diagnostic catheterization or PCI (0.6% vs 1.7%; OR 0.32; 95% CI 0.12-0.90). In patients undergoing PCI, there was a 60% reduction in the primary endpoint, but this was not statistically significant. This trial was stopped early by the data safety and monitoring board due to lower-than-expected event rates (13).

Overall, randomized trials evaluating TRA versus TFA consistently show fewer complications related to bleeding and vascular access and these benefits are confirmed in large meta-analyses that demonstrate decreased bleeding and VASCs, as well as mortality benefit in the ACS population, with TRA versus TFA (26, 27). Analyses of large registries support these findings (8, 14, 16, 28). Further insights will follow formal publication of data from the Safety and Efficacy of Femoral Access vs Radial Access in STEMI Trial (SAFARI-STEMI), a randomized trial that compares TRA to TFA in the setting of ST-elevation ACS with high-utilization of bivalirudin and vascular closure devices as bleeding avoidance strategies ([NCT01398254](#)) (29). Taken in total, the evidence evaluating outcomes in TRA versus TFA has led to recommendations that a “radial first” strategy may be reasonable to maximize patient safety (18).

IMPACT ON EARLY AMBULATION AND LENGTH OF STAY

Patients have reported a strong preference for earlier ambulation and decreased LOS (22). Although the RIVAL trial of over 7,000 randomized patients found no difference in LOS between TRA and TFA arms (4 days vs 4 days, $p = 0.18$) (10), multiple subsequent studies have shown that patients undergoing cardiac catheterization and PCI by TRA experienced early ambulation and decreased LOS compared to those performed by TFA. By anatomical location alone, radial access has an advantage over femoral access for early ambulation. While bed rest times after femoral access may be shortened with the use of vascular closure devices or reduced femoral sheath diameters, this has been shown to increase procedural cost or decrease angiographic quality (30).

The RADIAMI trial demonstrated that among patients hospitalized with MI, TRA significantly reduced bed rest time by greater than 12 hours compared to TFA ($p < 0.003$) (31). Similarly, in the CARAFE study, bed rest times in patients undergoing TRA were halved compared to TFA (4.9 hrs vs 9.9 hrs, $p < 0.001$), and LOS was significantly reduced in TRA versus TFA (31 hr vs 42 hr, $p < 0.05$) (19). In a series of elderly patients having elective catheterization, radial access was also associated with earlier ambulation time (5 hrs vs 11 hrs, $p < 0.001$), though LOS was short in both radial and femoral access groups with no significant difference (32). These findings were confirmed in a meta-analysis of mostly non-randomized studies and show a consistent benefit in early ambulation favoring radial access over femoral access in elderly patients undergoing cardiac catheterization (33). The effect of

radial access on LOS has also been evaluated in large randomized trials of patients with ACS. In RIFLE-STEACS, patients undergoing TRA had statistically significant decreases in total hospital LOS and LOS in the intensive care unit versus TFA (3 vs 4 days, $p < 0.001$) (11). STEMI-RADIAL also showed a significant reduction in ICU LOS in the TRA versus TFA arm (2.5 vs 3.0 days, $p=0.0038$) (12).

These data show that a majority of randomized trials evaluating radial vs femoral access in the setting of ACS demonstrate advantage in radial access for decreasing time to ambulation and having potential for reduced LOS. In the setting of stable coronary disease and planned outpatient cardiac catheterization, early ambulation with radial access facilitates same-day discharge plans and is aligned with patient satisfaction priorities.

IMPLICATIONS FOR HEALTHCARE ECONOMICS

In efforts to motivate improvements in cost efficiency, payers have been exploring alternative payment models as part of a shift in the US healthcare system from volume-based to value-based reimbursement (34). The Centers for Medicare and Medicaid's Innovation Bundled Payments for Care Improvement (BPCI) initiative, commonly referred to as "bundled payments," has been continued as a voluntary program to incentivize high-quality, cost-saving care practices (34, 35). Through lower risk of bleeding and VASCs, earlier ambulation, and decreased LOS, TRA results in cost savings and safety benefits for patients, payers, hospitals, and the healthcare system as a whole. There is evidence of cost advantages in a range of catheterization settings (36-39). In the case of outpatient elective catheterizations, which make up approximately half of >600,000 PCI procedures performed annually in the United States, using TRA to facilitate efficient peri-procedural care and same-day discharge (SDD) has resulted in enhanced patient satisfaction and cost savings. (19-22, 36-42).

Evidence supports that a TRA approach is particularly beneficial in patients at higher bleeding risk, as bleeding is a costly complication associated with longer LOS. In an analysis of internal admission cost data compiled from five PCI centers, a TRA approach was performed in 17% of cases and was associated with decreased LOS (2.5 vs 3.0 days, $p<0.001$), less bleeding (1.1% vs 2.4%, $p = 0.002$), and a total cost savings of \$830 per admission (95% CI \$296-\$1,364, $p < 0.001$) when compared to TFA. There was no significant difference in procedural cost. Savings were greater in patients with higher bleeding risk, with a savings of \$642 in those with low bleeding risk that increased to \$1,621 in those with higher bleeding risk (36). These results were consistent with findings from a retrospective cohort analysis of patients undergoing 61,509 PCI procedures in the Premier database during a period of 2004-2009. In this study, TRA use was associated with decreased inpatient hospitalization cost of \$553 (\$11,736 vs \$12,288, $p = 0.033$). This savings was driven by an average LOS that was 0.3 days shorter in TRA vs TFA. Additionally, 20% of the savings was attributed to decreased bleeding complications, and as a result, it was proposed that cost savings of utilizing TRA would be maximized in those with highest risk of bleeding (37).

Additionally, in a 2008 analysis, Rao et al demonstrated that bleeding severity was positively associated with increases in LOS, with LOS increasing from 5.4 days in patients with no bleeding to 16.4 days in the event of severe bleeding ($p < 0.01$). This increase in LOS was accompanied by a rise in cost from \$14,282 in the case of no bleeding to \$21,674 with mild bleeding, \$45,798 with moderate bleeding, and severe bleeding at \$66,564 ($p < 0.01$). After adjustment for baseline patient characteristics, investigators determined that each moderate or severe bleeding event increased hospitalization costs by \$3,770 and each transfusion event increased costs by \$2,080, with LOS driving increased costs associated with complications. It was concluded that minimizing complications and LOS is key to lowering the cost of PCI (38).

In an analysis using NCDR CathPCI Registry and Medicare claims data to assess potential savings from various clinical pathways in PCI for both SDD and TRA, out of 279,987 PCI patients during 2009 to 2012, 5.3% of patients undergoing PCI were SDD and 9.0% of these cases were performed via TRA. In cost analysis of various pathways, the most cost-efficient pathway was using TRA with SDD costing \$13,389, followed by using TFA with SDD at \$13,913 (see Table 1). TFA with non-SDD (NSDD) was most costly at \$17,076. SDD was associated with an adjusted cost-reduction of \$3,502 (95% CI \$3,486-\$3,902). Comparing TRA vs TFA costs, TRA utilization reduced adjusted hospitalization cost by \$916 for all LOS included in the analysis (95% CI \$778-\$1035) (See Table 2). Patients being discharged same day were more likely to have undergone TRA versus TFA (13.5% vs 4.5%). It was found that replacing the common practice of TFA and NSDD with widespread adoption of TRA with default plans for SDD could result in a significant cost savings (39).

Systematic implementation of SDD for elective PCI has been described as a potential strategy for improving fiscal value as well as increasing patient satisfaction (40). It has been previously shown that patients prefer decreased LOS for catheterization. In one study, about half of surveyed patients reported discharge on the same day of elective PCI as a priority (22, 41). Furthermore, in an observational analysis of patients undergoing elective PCI, SDD patients were more likely to have undergone TRA compared to NSDD (42% vs 5%, $p < 0.001$). In total, more patients underwent TFA than TRA in both SDD and NSDD groups, but there was a marked increase in TRA utilization over time, with greater than 4-fold increase in the proportion of cases with radial access over a two-year period (7% to 30%). Among SDD patients, 99.3% were “extremely satisfied” with being discharged same day, and all these patients rated their overall care as “excellent care.” At follow-up, these SDD patients had zero adverse outcome events of mortality, bleeding, or VASC requiring treatment, and there was no difference in AKI. SDD patients had significantly lower median total PCI cost with a 39% savings in total cost per procedure (\$10,425 vs \$17,135, $p < 0.0001$). After propensity score adjustment, SDD resulted in cost savings of \$7,331 per case (95% CI \$4,370-10,292). Implementation of the patient-centered SDD program was projected to result in single-institutional savings of \$1.8 million annually based on end-of-study SDD and PCI rate and volume estimates. Cost savings were realized across all categories of medical costs, but the bulk of the saved costs were owed to decreases in variable direct costs including lab tests, medications, medical and surgical supplies, and physician and nursing expenses (42).

Institutional-level savings were confirmed in a nationally representative analysis of 672,470 elective PCIs across 493 US hospitals in the Premier Healthcare Database (40). In this analysis, the unadjusted rate of SDD was 9.1% of all cases, although this rate was adjusted to 3.5% after accounting for high levels of inter-hospital practice variation. The higher unadjusted rate suggested that a few larger centers performing large numbers of SDD procedures resulted in a skewing of the unadjusted rate. Investigators concluded that SDD was significantly more likely in institutions performing TRA approach 20.6% of the time (incidence rate ratio 1.45; 95% CI 1.40-1.50; $p < 0.001$). In the cost analysis, SDD was associated with an adjusted savings of \$5,128 (95% CI \$5,006-\$5,248) per procedure with highest savings in the areas of central supply and reduced room and board costs. These savings came without consequence to clinical outcomes, as SDD was not associated with a higher rate of rehospitalization for bleeding, AKI, or MI, and there was no difference in post-discharge mortality. The high rates of inter-hospital variation illustrated that institutional practices, rather than solely patient attributes, may influence the treatment one receives. This variation decreased over the 9-year study period, but during this time, there was a range of SDD rate that varied from as low as 0% to as high as 83%, and practice variability was still high at the conclusion of the study. These variations emphasize the importance of deliberate, data-driven implementations for successful and safe SDD programs. Nationwide utilization of such a program with SDD rates as observed in the top decile were projected to save the healthcare system approximately \$577 million annually based on NCDR elective catheterization procedure volumes (40).

BALANCING MEASURES OF TRANSRADIAL ACCESS

While studies have identified several benefits associated with TRA, there are limitations that must be acknowledged. Data from randomized trials reveal that TRA has been linked to higher rate of procedure failure, need for crossover to femoral access, and greater fluoroscopy time (9-13, 43, 44). In one study, radial artery spasm, subclavian tortuosity, and inadequate guide support were found to be the most common reasons for procedure failure (45). However, while crossover from radial to femoral access is associated with reduced patient satisfaction, the absolute increase in procedure failure risk with TRA is only 4% higher than TFA (RR 0.97, 95% CI 0.96-0.98) (22, 27). Additionally, TRA is associated with a learning curve that must be overcome prior to realizing the benefits (45). In less experienced operators, greater rates of failure requiring crossover to femoral access, increased contrast use, and longer fluoroscopy time have been observed (45). However, the learning curve is not prohibitive, and at a threshold of only 50 cases, failure rates approximate those of expert users (45). Lastly, among operators who perform a high proportion of transradial cases, it has been proposed that a potential exists for greater rates of VASCs during femoral crossover – the “Campeau Radial Paradox” (46). However, in this study it is possible that the paradox existed as patients selected for femoral access had more comorbidities than those selected for radial access; in fact, there was a higher incidence of risk factors for major vascular complications in the femoral group (46). Furthermore, a retrospective analysis of 235,250 TFA PCIs in the British Cardiovascular Intervention Society demonstrated no association between recent center femoral proportion or volume

and femoral access site complications (47). Nonetheless, this finding highlights the importance of maintaining skillsets in both radial and femoral access.

CONCLUSION

In recent years, there has been growing adoption of TRA utilization for all types of cardiac catheterization with substantial evidence of safety, comfort, and economic advantages. In addition to reduced complications, particularly bleeding and vascular events, there are data demonstrating increased patient satisfaction, less pain and discomfort, earlier ambulation, and reduced LOS with TRA versus TFA. Furthermore, the substantial cost savings associated with TRA PCI through reduced complications and LOS underscore the potential for this technique to save millions in US healthcare costs. While these advantages have been noted widely in the literature, there are challenges to realizing these benefits, including a steep operator learning curve, ability to gain and maintain experience in TRA and TFA, and practice variation between hospitals and operators. Overall, these data underscore the value of the radial approach for cardiac catheterization and PCI for improved patient safety, greater patient satisfaction, and substantially lower healthcare spending. There are few therapies in medicine that improve patient outcomes at a lower cost – transradial access for PCI is one of the most robust examples.

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Key Points

- Transradial access improves clinical outcomes, primarily through decreased bleeding and vascular access site complications, and has demonstrated a mortality benefit in patients with acute coronary syndromes.
- In surveys, patients report a preference for transradial over transfemoral access for cardiac catheterization due to greater overall comfort, less pain, and decreased ambulatory impairment.
- Transradial access offers cost savings over transfemoral access, primarily through decreased length of stay, reduced resource utilization, and reduced rates of complications.
- Transradial access facilitates same-day discharge, leading to increased patient satisfaction and better healthcare value, particularly in an era of alternative payment models and bundled payments.

Synopsis

This review summarizes the impact of transradial access for cardiac catheterization and percutaneous coronary intervention related to patient satisfaction, patient safety, and healthcare costs. In studies comparing transradial versus transfemoral approach, transradial access causes less bleeding, less vascular access site complications, and provides a mortality benefit in patients with acute coronary syndromes. Transradial access improves patient satisfaction related to site tolerability by reducing pain and discomfort, and facilitating early ambulation with reduced length of stay. Cost savings associated with shorter stays, reduced resource utilization, and fewer complications have demonstrated the potential of increased transradial adoption to substantially reduce healthcare spending. Challenges influencing these benefits include the operator learning curve, and radial access practice variations across hospitals and operators. Taken in total, the existing randomized and observational data strongly support radial access for improved safety, patient satisfaction, and significant cost savings.

Table 1:

Adjusted Costs of Percutaneous Coronary Intervention By Care Pathway Groups adapted with permission from Amin AP, Patterson M, House JA, et al. Costs Associated with Access Site and Same-Day Discharge Among Medicare Beneficiaries Undergoing Percutaneous Coronary Intervention: An Evaluation of the Current Percutaneous Coronary Intervention Care Pathways in the United States. JACC Cardiovasc Interv. 2017;10(4):342-351

Care Pathway Group	Adjusted PCI Cost (\$)	95% CI (\$)
SDD	13,256	13,091-13,406
NSDD	16,753	16,673-16,833
TRA (SDD & NSDD)	15,786	15,642-15,928
TFA (SDD & NSDD)	16,701	16,620-6,787
TRA-SDD	13,389	13,161-13,607
TRA-NSDD	16,420	16,298-16,553
TFA-SDD	13,913	13,771-14,060
TFA-NSDD	17,076	16,999-17,147

Abbreviations: PCI – Percutaneous Coronary Intervention, CI – Confidence Interval, SDD – Same-Day Discharge, NSDD – Non-Same-Day Discharge, TRA – Transradial Access, TFA – Transfemoral Access

Table 2:

Adjusted Cost Difference Between Care Pathways adapted with permission from Amin AP, Patterson M, House JA, et al. Costs Associated with Access Site and Same-Day Discharge Among Medicare Beneficiaries Undergoing Percutaneous Coronary Intervention: An Evaluation of the Current Percutaneous Coronary Intervention Care Pathways in the United States. JACC Cardiovasc Interv. 2017;10(4):342-351

Care Pathway Group	Cost Difference (\$)	95% CI (\$)	P-Value
TRA vs TFA	−916	−1,035 to −778	<0.001
SDD vs NSDD	−3,502	−3,648 to −3,347	<0.001
TRA SDD vs TRA NSDD	−3,035	−3,273 to −2,825	<0.001
TRA SDD vs TFA SDD	−527	−776 to −295	<0.001
TRA SDD vs TFA NSDD	−3,689	−3,902 to −3,486	<0.001
TRA NSDD vs TFA SDD	2,508	2,324 to 2,680	<0.001
TRA NSDD vs TFA NSDD	−652	−765 to −534	<0.001
TFA SDD vs TFA NSDD	−3,160	−3,299 to −3,027	<0.001

Abbreviations: CI – Confidence Interval, SDD – Same-Day Discharge, NSDD – Non-Same-Day Discharge, TRA – Transradial Access, TFA – Transfemoral Access