Radiation Exposure with the Radial Approach for Diagnostic Coronary Angiography in
a Centre Previously Performing Purely the Femoral Approach

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Abstract

Introduction: Use of the radial approach for coronary angiography and percutaneous coronary intervention (PCI) is known to improve many patient outcome measures. However, there is some concern that it may be associated with increased patient radiation exposure. This study explores radiation exposure with the radial approach compared with the femoral approach in a centre previously performing purely femoral approach.

Patients and Methods: Data was collected retrospectively for all patients undergoing diagnostic coronary angiography over a six month period. PCIs and procedures with inherent technical difficulty or use of additional techniques (graft studies, optical coherence tomography, fractional flow reserve) were excluded. Dose area product (DAP) and fluoroscopy time (FT) were analysed for all remaining procedures (n=389), comparing radial (n=109) and femoral (n=280) approaches.

Results: The overall mean FT for transradial cases (7.45 mins) was significantly higher than for transfemoral cases (4.59 mins; p<0.001). The overall mean DAP for transradial cases (95.64 G Gycm²) was significantly higher than for transfemoral cases (70.25 Gycm², p<0.05)). Neither the FT nor the DAP decreased over the six month period.

Conclusion: The radial approach was associated with significantly higher DAP and FT compared to the femoral approach during an initial introductory phase which was likely insufficient to develop radial proficiency. The results of this study are consistent with previous studies and may influence choice of access for non-emergent diagnostic coronary angiography before radial proficiency has been established, particularly for patients more susceptible to radiation risks.

Keywords
Coronary angiography; coronary artery disease; radiation dosage; radial artery; femoral
artery
Introduction

Since the introduction of the transradial approach to coronary angiography over 20 years ago, there has been much interest in this method and the possible advantages over the traditional transfemoral method [1,2,3,4]. Centres throughout the world now use the radial approach not only as an alternative to the femoral approach, but as the default arterial access [1,2,5,6].

Previous studies have attempted to determine whether or not there is a difference in patient radiation exposure for coronary angiography and percutaneous coronary intervention (PCI) depending on the arterial access route. The results of these studies have varied, with most studies finding measures of radiation exposure to be higher with radial access [2,4,7,8,9,10,11,12,13,14], some showing no appreciable difference between access routes [15,16,17] and one study finding higher exposure with femoral compared to radial access [18]. Differences in the results of these studies may be attributed to many study design and patient factors, including study methodology, different measures of radiation exposure, patient demographics and variability in included procedures. Many studies also had broad objectives, looking at many aspects of procedural safety and effectiveness, rather than focusing purely on patient radiation dose [7,8,9,10,11,13,15,18,19].

Another explanation for the significant variability of results between studies is operator experience with the radial approach. It has been demonstrated that radiation exposure with the radial approach is higher for an individual operator until he/she becomes radial proficient and higher in low-volume centres [5,6,19,20,21]. As such, it would be expected that studies with radial proficient operators would have less difference in radiation exposure between the radial and femoral approaches.
This study explores radiation exposure for diagnostic coronary angiography with the radial approach in a centre previously performing purely femoral approach. Unlike some previous studies, only standard diagnostic coronary angiograms (without additional techniques or PCI) are included and radiation exposure is the primary outcome examined. By allowing cardiologists to choose arterial access and imaging methods, this study demonstrates the true radiation exposures that occur in the cardiac catheterisation laboratory in our centre. While this is not generalisable to all centres, it may provide an approximation of radiation exposure in other teaching hospitals with similar case volume.

Methods

Study Design and Patient Population

This study was undertaken in a large metropolitan hospital in Melbourne. Coronary angiograms were performed by five experienced interventional cardiologists and one interventional cardiology fellow. Training cardiology registrars only performed procedures in conjunction with an experienced interventional cardiologist or the interventional fellow.

Coronary angiograms were performed in two new cardiac catherisation laboratories, both equipped with Phillips Allura Xper biplane cardiovascular x-ray systems (FD10 & FD20 models). Total procedural radiation dose is reported by these units as dose area product (DAP) in Gycm² and fluoroscopy time (FT) in mins:secs.

Retrospective data was collected for all diagnostic coronary angiograms performed over a six month period from April to October 2012. Data was obtained primarily from the radiographers' record and cardiologists’ reports, with additional information obtained as needed from procedural data, cardiac catheterisation admission forms, hospital admission forms and patient notes. Patient age, height and weight was recorded in whole numbers.

This study covers the period of time during which the radial approach for coronary angiography was being formally introduced in a centre that was previously preferentially
using the femoral approach. Each of the cardiologists had some previous experience with using the radial approach. Prior to April 2012 most operators used the radial approach very infrequently, generally only where there was a relative or absolute contraindication to using the femoral approach. One cardiologist had begun using the radial approach in 2011 and may have achieved radial access proficiency, as defined by a European Society of Cardiology (ESC) Working Groups [6], by the start of our study period. The remainder of the operators were not radial proficient at the start of the study and remained on the learning curve (were not yet radial proficient) at the end of the study.[AV5]

Choice of arterial access route for each procedure was determined by the interventional cardiologist, based on operator preference and clinical indications and contraindications. While the interventional cardiologists were actively trying to increase use of the radial approach during this time period, there was no pressure to use the radial approach if they felt that the femoral approach would be better for any individual patient or situation.

Imaging parameters, including beam filtration, field size and frame rate were set by radiographers as per department protocols designed to minimise radiation exposure while optimising image quality. These were adjusted as required based on radiographers’ judgement, to produce optimal images for each patient.

Exclusion Criteria
This study looked only at standard diagnostic coronary angiograms and not interventional procedures, due to the variable nature and differing technical and procedural characteristics of PCIs, compared to diagnostic procedures. In the setting of interventional procedures, radiation dose is far more likely to be influenced by such factors as the number, location and nature of lesions being treated, as well as the nature of the intervention undertaken (angioplasty, stenting, rotational artherectomy, thrombus aspiration).

Limiting the study population to only those patients undergoing diagnostic procedures limits the number of variables likely to influence patient radiation exposure. Procedures that
incorporated any degree of intervention, whether planned or unplanned, successful or unsuccessful, were not included in the study population.

Exclusion criteria were as follows and are demonstrated in Table 1:
- procedures which employed additional diagnostic techniques: graft studies, fractional flow reserve (FFR), optical coherence tomography (OCT), right heart studies (RHS)
- procedures which involved insertion of devices (intra-aortic balloon pump or pacing wires)
- change in arterial access route (radial to femoral or femoral to radial)
- use of the brachial artery as the access route
- missing, incomplete, incorrect or illegible DAP or FT data

Procedures in which multiple attempts were made to access the same artery were not excluded from the study. Similarly, cases in which the contralateral site was accessed after failure to access the initial site (eg. left femoral access obtained after failure to obtain right femoral access) were not excluded. Procedures in which patient height or weight data was missing were not excluded.

Statistical Analysis
Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel 2011. Univariate analysis was performed using the student t-test and chi-square test. Multivariate analysis using linear regression was then performed on relevant variables to determine if there were any independent associations. Statistical significance was defined as p-value <0.05.

Results
During the six-month period of April 16 2012 to October 15 2012, 426 patients underwent diagnostic coronary angiography without PCI. Of these, 79 patients were excluded from the study based on the exclusion criteria previously described (see Table 1).

Patient Demographics
Patient demographics are demonstrated in Table 2. Analysis of the patient demographics for
the radial and femoral groups demonstrated no statistically significant difference in patient age (radial mean 65.1, femoral mean 63.6, p>0.05) but there was a statistically significant difference in height (radial mean 169.1, femoral mean 166.7, p<0.05), weight (radial mean 89.3, femoral mean 82.4, p<0.01) and body mass index (BMI) (radial mean 31.0, femoral mean 29.5, p<0.05) for the two groups.

**Choice of Access**

Of the 389 patients included in the study, 109 patients (28%) underwent diagnostic coronary angiography via the radial approach and 280 patients (72%) via the femoral approach. Only two cases used left radial artery access, both of these after failed right radial artery access. In the first month of the study, the radial approach was used for only 20% of patients. This increased to 40% by the fifth month, then decreased to 32% in the sixth month (Figures 1 and 2, Table 3). Use of the radial approach in the second half of the study period (37%) was higher than use of the radial approach in the first half of the study period (20%).

**Operator**

Univariate analysis by chi-square test demonstrated that cases in the radial and femoral groups were not undertaken by significantly different types/combinations of operators (consultants, fellows, registrars, consultant with fellow, consultant with registrar, etc). We were unable to analyse for each individual operator (see Limitations).

**Fluoroscopy Time**

Mean FT was consistently higher each month for transradial cases (Figure 3, Table 3). The overall mean FT for transradial cases (7.45 mins) was significantly higher than for transfemoral cases (4.59 mins; p<0.001). FT did not decrease over the six month period.

Multivariate analysis demonstrated that radial access remained an independent predictor of increased FT when adjusted for BMI and gender. Gender was another independent predictor of FT, with male gender associated with increased FT, but BMI was not.
Dose Area Product

Mean DAP was higher for transradial cases throughout the study period with the exception of month 5 (Figure 4, Table 3). The overall mean DAP for transradial cases (95.64 Gycm²) was significantly higher than for transfemoral cases (70.25 Gycm², p<0.05). DAP did not decrease over the six month period.

Multivariate analysis demonstrated that radial access remained an independent predictor of increased DAP when adjusted for BMI and gender. Gender and BMI were other independent predictors of DAP, with male gender and increased BMI associated with increased DAP.

Discussion

Choice of Access

Many potential factors may contribute to operator choice of arterial access, including patient factors and individual preference. This study was undertaken during a six month period when the radial approach was being formally introduced into routine use at our centre. Prior to this, all cardiologists had previous training in, and exposure to, the radial approach but only one operator was radial proficient [6].

During the period under study, operators were allowed to choose access route on a case-by-case basis. Patient gender, height, weight and BMI were different between the radial and femoral groups but not patient age. This suggests that the major factors involved in choice of access route were patient gender, body habitus, clinical factors and operator preference, at least in the early uptake phase of radial angiography.

Fluoroscopy Time

Consistently higher FT were observed for the radial approach throughout the study and the overall FT for the two arterial access sites was statistically significant.

As the length of each angiographic run is generally determined by coronary arterial flow (imaging from contrast injection to contrast washout), this suggests that the increased
fluoroscopy time for radial studies was due to increased fluoroscopic screening during placement of catheters. This is in line with the increased technical difficulty of navigating the arterial system from the radial artery to the coronary ostia during the learning curve [6].

While it may not be necessary to use fluoroscopic guidance to navigate guide wires and catheters from the common femoral artery to the aortic arch, it is obviously important to visualise navigation from the proximal right or left subclavian artery to the coronary ostia, in order to prevent unintentional catheterisation of the carotid arteries and the potential risk of dislodgement of an embolus into the cerebrovascular circulation [6]. While studies have demonstrated that there is no increased risk of stroke with the radial approach, this is in the context of operators taking due diligence to reduce stroke risk [6,22,23]. As such, it may be impractical for operators to reduce FT during this particular part of the procedure, however, overall fluoroscopy time can still be minimised with increasing experience and radial proficiency [6,20].

**Dose Area Product**

Mean DAP over the six month period of our study was significantly higher in the radial group. While there are many factors that can affect DAP, most of these are not modifiable in the context of maintaining adequate visualisation of the coronary arteries. All operators and radiographers are trained in radiation safety and, according to the ALARA (as low as reasonably achievable) principle, aim to minimise radiation dose while maintaining diagnostic image quality [24]. As previously mentioned, it is difficult to reduce screening time during the learning curve for the radial approach [20] (which would also decrease DAP). Using altered beam filtration, smaller field sizes, more collimation and less tube angulation can decrease DAP but also affects image quality. As such, it is a fine balance to reduce DAP without compromising the diagnostic value of the procedures.
Limitations

This study was conducted at a single centre, giving relatively low patient numbers and making our results generalisable only to other teaching centres with similar case volume [AV10].

As this was a retrospective observational study, cardiologists chose the access route based on their preferences and patient factors. While this reflects real clinical practice, a lack of randomisation has the potential to introduce bias in patient selection and, therefore, confounding variables [AV11]. However, multivariate analysis demonstrated that access route remained an independent predictor of both FT and DAP when adjusted for BMI and gender.

Our study only examined radiation dose over the first six months of implementation of transradial coronary angiography in a centre previously using only the femoral approach. Studies have demonstrated that the higher radiation exposure associated with radial access is, at least in part if not completely, due to lack of operator experience with this technique [6,21]. While the duration of this learning curve is still unclear and depends on case volume, the time period and radial volume involved in this study was likely less than required to establish radial proficiency [1,2,4,5,6,7,12,13,17,19,25,26]. If the study was continued for a longer period of time, we may expect to see an improvement in radiation exposure parameters.

Another limitation of our study is that we were unable to analyse for the effect of individual operators on radiation exposure. As our centre is a teaching hospital, cases very often involve trainees with varying levels of experience and involvement in each case, from primary operator to assistant. Some cases involved more than one consultant or more than one trainee. Analysing for each combination of operators would have resulted in excessively small sample sizes and it was not possible to retrospectively determine the degree of involvement of each operator in each case, in order to identify a primary operator.

Other factors which may not have been corrected for include use of cardiac swing, angioseal closure in femoral cases, or differences in performance of left ventriculography and/or
aortography. Use of cardiac swing and angioseal closure is minimal at our centre, and ventriculography is routine in all cases except in severe renal failure so the impact of any potential differences would be minimal.

General Considerations

Studies have clearly demonstrated improved outcomes for transradial coronary angiography and PCI, compared to the traditional femoral approach, including reduced mortality [2,3,4,5,6,7,8,9,11,12,13,15,17,18,19,22,23,27,28]. The use of radial angiography has therefore increased, despite the initial increased technical difficulty of this approach [2,4,6,17].

While the benefits of the radial approach are recognised, there has been relatively little consideration of the potential for higher patient radiation exposure, especially during the time taken to develop radial proficiency [1,2,4,5,6,7,8,9,11,12,14,16,18,25]. Radiation exposure is not a primary consideration when determining access route for coronary angiography or PCI in elderly patients with acute coronary syndromes [14]. However, a growing number of younger patients, including women of child-bearing age, are undergoing coronary angiography and PCI, for whom radiation exposure must be a primary consideration [16].

The radiographer may minimise radiation dose by beam collimation, by decreasing the x-ray frame rate or by adding filters to the x-ray beam [4,5,12,14,24]. However each of these modifications has implications for image quality and so the need for radiation dose minimisation must be balanced with the need for adequate visualisation of coronary artery anatomy and pathology [24].

More important are patient related factors which have a significant impact on radiation dose, however these factors are either not modifiable (age, gender, arterial tortuosity) or not modifiable for the purpose of the procedure (BMI, peripheral arterial disease). The most important patient factors in determining radiation dose are tissue thickness and density,
which are usually estimated by BMI but may also be affected by such factors as breast size and muscle bulk [24]. These factors may also affect the choice and difficulty of vascular access and operators may preferentially use radial access for these patients [7,9,14,15]. This was demonstrated in our study by the fact that the radial group had a significantly higher BMI than the femoral group.

The use of additional techniques such as FFR and OCT is determined by clinical indications such as uncertain functional significance of stenoses. Additional imaging is required when a patient has previously undergone coronary artery bypass graft surgery (CABGS) to examine graft patency. While these techniques may increase radiation exposure, the radiation risk is far outweighed by the need to diagnose native coronary artery or grafted vessel stenosis. As previously mentioned, our study excluded any cases that used additional techniques or included graft studies, in recognition of the radiation exposure attributable to these factors.

Conclusions
This study demonstrates that there is increased radiation exposure (FT and DAP) associated with use of the radial approach for diagnostic coronary angiography during an initial introductory phase. However, this must be balanced against the many benefits of radial access over femoral access, especially in PCI and STEMI. Interventional cardiologists should consider the radiation safety implications of using the radial approach for non-emergent procedures performed before they have established radial proficiency. This is particularly important for patients more vulnerable to the effects of radiation exposure, including women of child-bearing age and younger patients, who are also more likely to undergo multiple coronary angiograms in their lifetime. Further research is needed to determine whether dose to particular radio-sensitive tissues, such as breasts, ovaries and testes is influenced by choice of arterial access.

Acknowledgements
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References


## Tables

### Table 1: Excluded studies

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<th>468</th>
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<td>All included studies</td>
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<tr>
<td>Excluded Graft studies</td>
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<tr>
<td>RHS</td>
<td>2</td>
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<tr>
<td>IABP</td>
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<td>Bi-ileofemoral angiogram</td>
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<td>OCT</td>
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<tr>
<td>FFR</td>
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<td>Limited study</td>
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<tr>
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<tr>
<td>IABP + pacing wires</td>
<td>1</td>
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<tr>
<td>OCT + limited study</td>
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<tr>
<td>Limited study + dual access</td>
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<tr>
<td>Radiation exposure data missing or illegible</td>
<td>7</td>
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<tr>
<td><strong>Total excluded</strong></td>
<td>79</td>
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**Number of studies after exclusion criteria**

| 389 |

RHS- right heart study; IABP- intra-aortic balloon pump; OCT- optical coherence tomography; FFR- fractional flow reserve
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<tr>
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<td>280</td>
<td>389</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Female [%]</td>
<td>31 [28]c</td>
<td>110 [39]c</td>
<td>141 [36]</td>
</tr>
<tr>
<td>Male [%]</td>
<td>78 [72]c</td>
<td>170 [61]c</td>
<td>248 [64]</td>
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<tr>
<td><strong>Mean age</strong> (years)</td>
<td>65.1 [12.9]</td>
<td>63.6 [12.6]</td>
<td>64.0 [12.6]</td>
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<td><strong>Mean height</strong> (cm)</td>
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<td>166.7 [9.4]a</td>
<td>167.4 [9.2]</td>
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<td><strong>Mean weight</strong> (kg)</td>
<td>89.3 [22]b</td>
<td>82.4 [18.5]b</td>
<td>84.4 [19.8]</td>
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<td><strong>Mean BMI</strong> (kg/m²)</td>
<td>31.0 [7.5]a</td>
<td>29.5 [5.9]a</td>
<td>29.9 [6.4]</td>
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Square brackets indicate standard deviation unless otherwise defined.
BMI - body mass index
a- p<0.05 by student t-test; b- p<0.01 by student t-test; c- p< 0.05 by chi-square test
Table 3: Summary of results - use of radial access and radiation exposure

<table>
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<th>Parameter</th>
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<td>Month 2</td>
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<tr>
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<td>88.21 [62.56]</td>
<td>94.88 [64.95]</td>
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<tr>
<td></td>
<td>Femoral</td>
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<td>61.18 [39.02]</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>74.87 [44.7]</td>
<td>68.67 [48.15]</td>
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</table>

Square brackets indicate standard deviation unless otherwise defined
DAP- dose area product; FT- fluoroscopy time
ᵃ- p<0.05; ᵇ- p<0.01; ᶜ- p<0.001
Figures and Legends

**Figure 1:** Number of cases using radial and femoral approach over the six month period.
Figure 2: Percentage of cases using radial and femoral approach over the six month period.
Figure 3: Mean fluoroscopy time (FT) for radial and femoral access over the six month period.
Figure 4: Mean dose area product (DAP) for radial and femoral access over the six month period.
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