American Journal of Medicine Studies, 2022, Vol. 10, No. 1, 1-7
Available online at http://pubs.sciepub.com/ajms/10/1/1
Published by Science and Education Publishing
DOI:10.12691/ajms-10-1-1

Transradial Access - A Predictive Model to Assess Radial Artery Diameter

Michael Brockman[1,*], Jarren Adam[2], Cassandra De La Torre[3], Lucas Achkarian[4], Robert Hanna[5]

[1]Texas Tech University Health Sciences Center El Paso
[2]St. Joseph's Medical Center-Stockton, California
[3]Adventist Health White Memorial
[4]Cornell University
[5]Banner Desert Medical Center
*Corresponding author: mbrockman1@gmail.com

Received October 05, 2022; Revised November 11, 2022; Accepted November 20, 2022

Abstract ***Purpose:*** Currently, the femoral artery is the most common vascular access site for interventional procedures. With medical instrument advancements and improved procedure techniques, the radial artery is becoming the preferred vascular access point for interventionalists due to decreased complication risks and improved recovery times. Although transradial procedures have improved clinical outcomes, additional, pre-interventional imaging is often required to assess the capacity of the smaller radial artery when comparing the femoral artery. This study explores an alternative, machine learning-based method to predict radial artery adequacy for interventional procedures without the need for additional, pre-intervention imaging. ***Materials and Methods:*** Whole human body computed tomography (CT) scans were collected from New Mexico's Decedent Image Database. The inclusion criteria were decedents between the ages of 18 to 99, who died of natural causes, and had no identifiable decomposition. The decedent's femoral artery diameter, sex assigned at birth, age, carcinogen exposure, smoking history, drinking history, substance usage, height, and weight were recorded. Using Horos Project DICOM viewer, the right femoral and right radial artery of each CT scan was measured. The resulting measurements were then passed through the Python 3.9 module, Scikit-Learn, to create a predictive random forest classifier. ***Results:*** Femoral and radial artery diameters were measured on 127 decadents. The predetermined threshold for radial artery usability diameter was 2.5 mm, which was based on guidance from Hobby et al's publication, *Transradial Access: A Comprehensive Review*. The performed linear regression of femoral artery diameter explains 54.9% of the variability found in radial artery diameter. After one-thousand training iterations, the random forest classifier model achieved a mean testing accuracy of 85.71% in predicting if the radial artery equal to or greater than 2.5mm.

Keywords: *the presented study preliminarily suggests that femoral artery diameter and other parameters, such as age, height, weight, and smoking history, can be used for training a random forest classifier model to assess radial artery diameter*

Cite This Article: Michael Brockman, Jarren Adam, Cassandra De La Torre, Lucas Achkarian, and Robert Hanna, "Transradial Access - A Predictive Model to Assess Radial Artery Diameter." *American Journal of Medicine Studies*, vol. 10, no. 1 (2022): 1-7. doi: 10.12691/ajms-10-1-1.

1. Introduction

Prior to the advent of endovascular methodologies, medical procedures often entailed incredibly invasive and open surgeries [1,2,3]. Technological and medical advancements have provided new opportunities to reduce the necessity for open procedures in favor of minimally invasive procedures [2]. Currently, the transfemoral artery route is the standard of care for minimally invasive endovascular procedures. It is used in multiple medical disciplines from cardiology for cardiac catheterizations to vascular surgery for endograft placements to interventional radiology for embolization of bleeds and tumors [4,5]. Though transfemoral artery-based procedures have been the most common vascular access route, transradial artery procedures are an alternative vascular access route with many advantages over transfemoral procedures.

When comparing the transradial approach to the transfemoral approach, various procedures have been shown to be equally, if not more, clinically beneficial [6]. In side-by-side comparisons, patients who have experienced transradial procedures benefit from decreased pain, complications, and improved recovery time when compared to patients who have experienced the same procedure via transfemoral access. Beyond clinical benefits, when surveyed, patients have been shown to have a stronger preference for transradial artery procedures when compared to transfemoral artery procedures [7,8,9].

However, there are some challenges which are slowing the broader adoption of transradial access for many interventionalists. For one, the transradial approach requires additional training and time for an interventionist to pass instruments across a more tortuous and smaller vascular space [10,11,12]. Another is the assumed sufficient capacity of the femoral artery due to it being a larger artery compared to the radial artery.

But if a patient is to undergo a transradial procedure, a Barbeau test and ultrasound of the arm are often performed [6,13,14]. The additional cost, time spent, and burden on the patient could offset the benefits of transradial procedures. This study explores the possibility of using machine learning as an adjunct to vascular assessment in attempts to encourage greater adoption of transradial procedures.

2. Materials and Methods

The data utilized for this study was gathered from The New Mexico Decedent Image Database maintained by the University of New Mexico[1] [15]. The image database contains over 15,000 whole human body CT scans of volunteer individuals who died between the years 2010 to 2017. CT scan slice thickness is 1 mm with 0.5 mm overlap. Along with the CT scans, demographic and biographic data is available, as well as pathologic assessment of the body's decomposition state at time of the CT. The database provides search tools to apply inclusion and exclusion criteria.

The inclusion criteria for the study were decedents between the ages of 18 to 99 who died of natural causes and had no identifiable decomposition at time of the full body scan. Decedent's femoral artery diameter, sex assigned at birth, age, carcinogen exposure, smoking history, drinking history, substance usage, height, and weight were recorded. Using Horos Project[2] DICOM viewer, the right femoral and right radial artery of each CT scan were measured. The resulting measurements were then passed through the Python 3.9 module, Scikit-Learn, for further analysis. Each decedent's anonymity was preserved and any unnecessary information that could be used to de-anonymize the decedents were discarded.

3. Procedural Techniques

3.1. Data Collection

For each respective whole human body CT scan, The New Mexico Decedent Image Database organization provided accession numbers that could be used to refer to each case. These accession numbers also adhered to the Health Insurance Portability and Accountability Act (HIPAA), thus ensuring appropriate anonymity for each decedent. The only biographic and demographic data used for this study were decedent's sex, age, exposure to carcinogens, smoking history, drinking history, substance usage history, height, and weight.

The whole human body CT scans of 127 decedents were analyzed via open-source application, Horos, created by the Horos Project [16]. The remaining 14,873 decedents were excluded due to cause of death rendering measurements impossible as well as computational power constraints. Using the Horos application, the DICOM files of the CT scans were analyzed. Figure 1a and Figure 2a are examples of images similar in quality and anatomical location which were used for measurement of their respective arteries. Figure 1b and Figure 2b are of the same images but with their respective arteries measurements superimposed on the images. The right femoral artery and right radial artery diameter were measured for each decedent. Figure 3 displays a plot of the relationship of the femoral artery diameter to the radial artery diameter. The data was validated by repeating the measuring step, blinded to the initial results, then reporting the mean of the first and second right femoral artery and right radial artery diameter. The final results were reported in millimeters (mm).

Figure 1a. Example of upper extremity CT slice used for right radial artery measurement

Figure 1b. Example of upper extremity CT slice with coinciding right radial artery measurement label used for analysis

---

[1] https://nmdid.unm.edu/

[2] https://www.python.org/

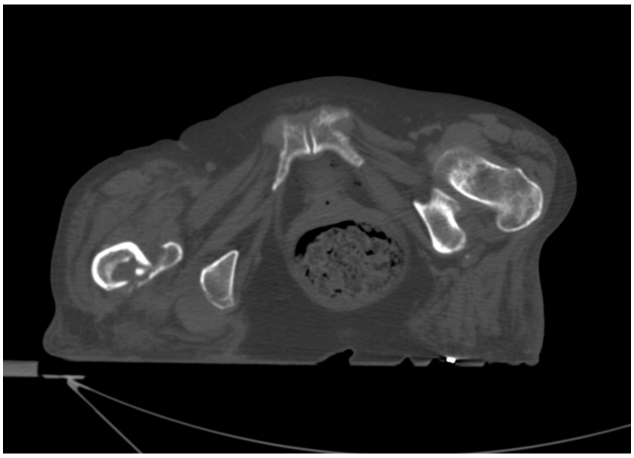


Figure 2a. Example of lower extremity/pelvic CT slice used for right femoral artery measurement

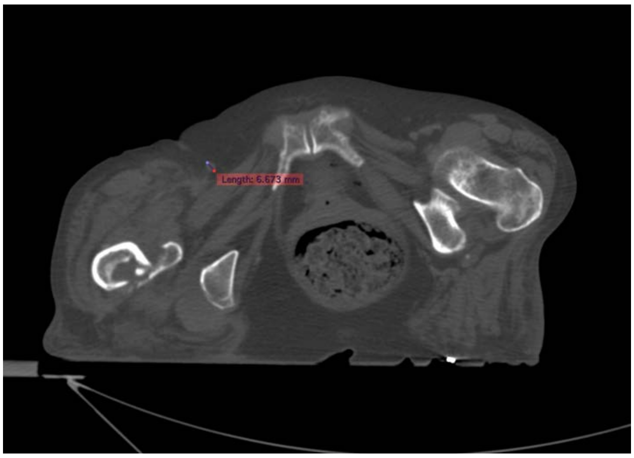


Figure 2b. Example of lower extremity/pelvic CT slice with coinciding right femoral artery measurement label used for analysis

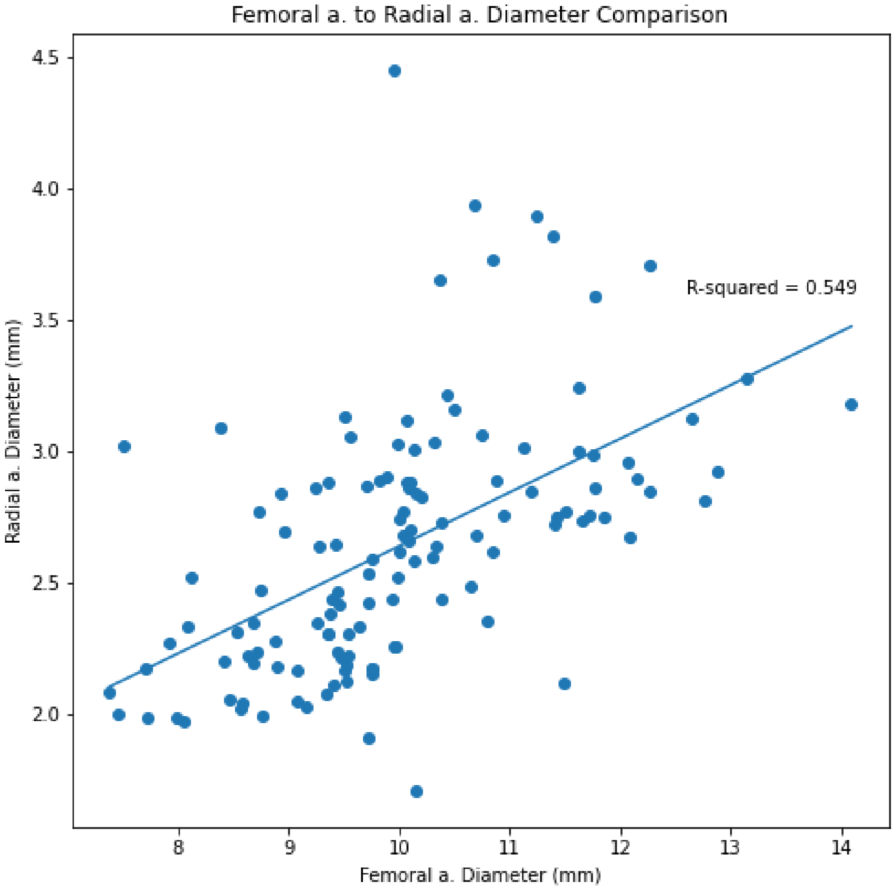


Figure 3. Comparison of femoral artery to radial artery diameter per decedent.

3.2. Analysis

Statistical analyses were performed leveraging open-source computer language, Python (3.9.1)[3], and open-source, web-based interactive computational environment, Jupyter notebook (Version 7.19.0)[4] [17,18]. Using the statistical, Python-based module, Scikit-Learn (Version 0.24.2)[5], the right radial artery diameters and right femoral artery diameters were passed through the random forest classifier model, a supervised machine learning algorithm. These data also contained the associated biographic and demographic features (height(cm), carcinogen exposure (1 if yes, 0 if no), smoking history (1 if yes, 0 if no), biological sex (1 if male, 0 if female), weight(kg), age (years), alcohol exposure (1 if any lifetime alcohol exposure, 0 if none), and recreation drug exposure (1 if any lifetime recreational drug exposure, 0 if none)) [19]. The random forest classifier model was trained using 127 decedents data. A radial artery diameter of 2.5mm or larger was used as the threshold for radial artery adequacy for transradial access. Scikit-Learn's random forest classifier yielded the relationship of the right femoral artery diameter to the right radial artery diameter when controlling for the provided variables.

---

[3] https://www.python.org/
[4] https://jupyter.org
[5] https://scikit-learn.org/stable/index.html

4. Results

4.1. Constructing the Random Forest Classifier

Prior to training the random forest classifier, Figure 3 reveals a direct correlation between femoral and radial artery diameter. The linear regression of the patient data resulted in an R^2 value of 0.549. Thus, the linear regression of femoral artery diameter explains 54.9% of the variability found in radial artery diameter.

After performing 1,000 iterations of the random forest classifier model, the model achieved a mean testing accuracy of 85.71% in predicting if the radial artery equal to or greater than 2.5mm. The maximum accuracy throughout the 1,000 iterations was found to be 92.59%, the minimum accuracy was found to be 74.07%, and the standard deviation was 2.76%. The changes in model accuracy over the final 100 iterations are graphically represented in Figure 4.

4.2. Interpreting the Random Forest Classifier

Ultimately, after running the multiple iterations, the produced random forest classifier can be visualized in Figure 5. Figure 5 displays the model's weights for the given classifier to produce the predictions. The more orange a given cell is in Figure 5, the more confident the model is that the subject's radial artery is equal to or greater than 2.5mm, while the more blue indicates the higher confidence that the radial artery is less than 2.5mm. The random forest classifier is used like a decision tree. When the node's statement is true, one moves to the left to the next node, and false to the right.

An example usage of Figure 5 would be the presentation of a 35-year-old male with no history of smoking use, no exposure to carcinogens (asbestos, chewable tobacco, radon, etc.), no substance use (heroin, methamphetamine, phencyclidine, etc.) history, who was found to have a femoral artery luminal diameter of 9.00mm. At the initial node, 'Carcinogen Exposure?', since the example patient has exposure, the node is true. The next node in the chain is 'Sex = Female.' This node is false thus one advances to the right most node in the sequence. The next node in the sequence, 'Substance Use Exposure?', is true thus one advances to the left node in the sequence. The next node, 'Femoral a. Diameter <= 9.48', is true thus one advances to the left node in the sequence, however the following node, Femoral a. Diameter <= 8.07,' is false thus one advances to the right most node. The final node in the sequence, 'Age <= 60.5,' is true and the example reaches the final node in the sequence. The final node is orange which corresponds to a high degree of confidence that the radial artery is greater than 2.5mm based on 5 decedent samples with similar presentation.

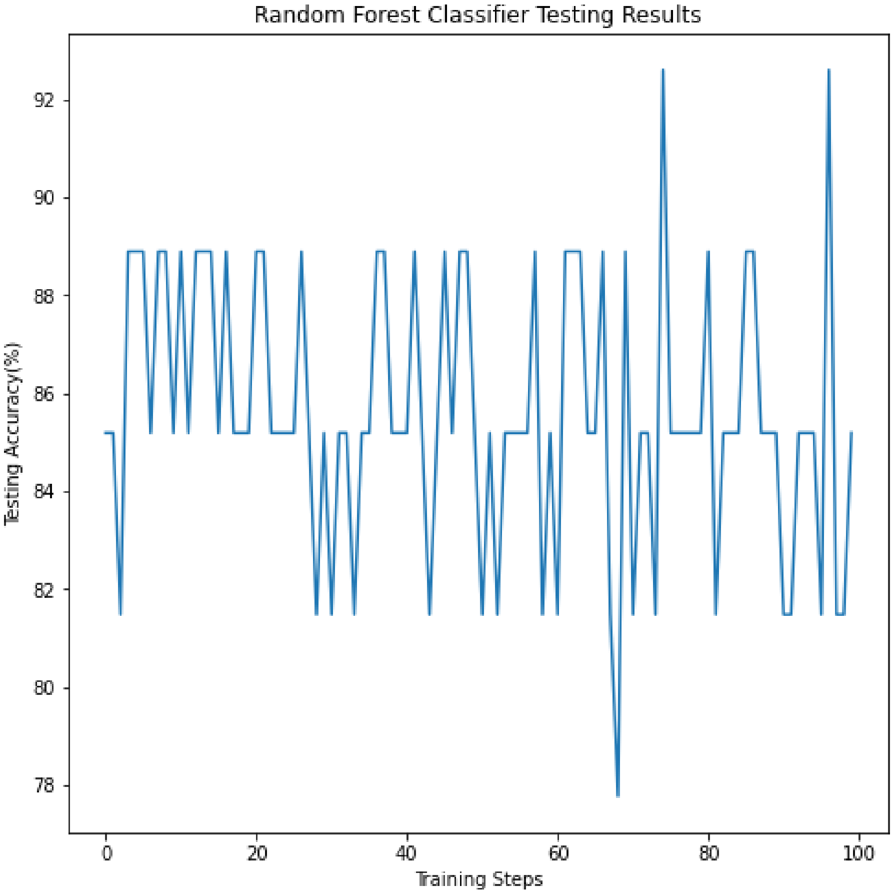


Figure 4. Results of final 100 iterations of random forest classifier training steps.

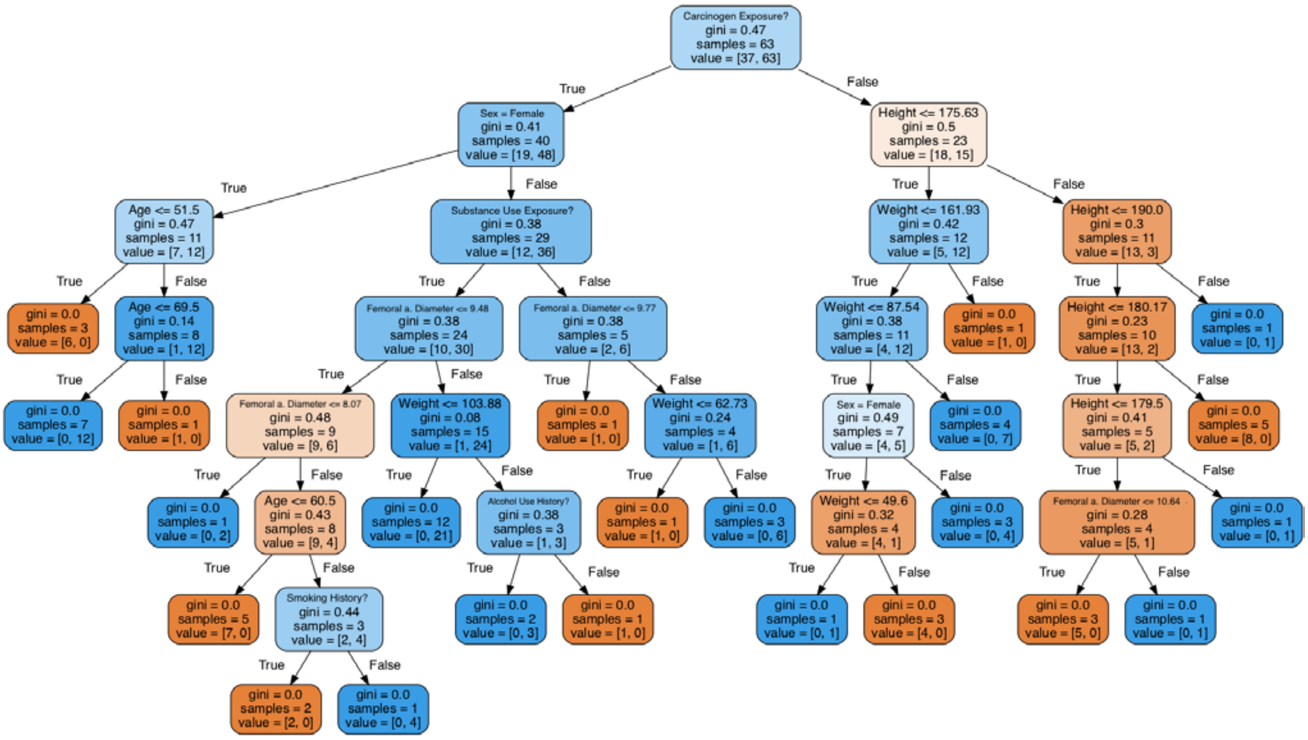
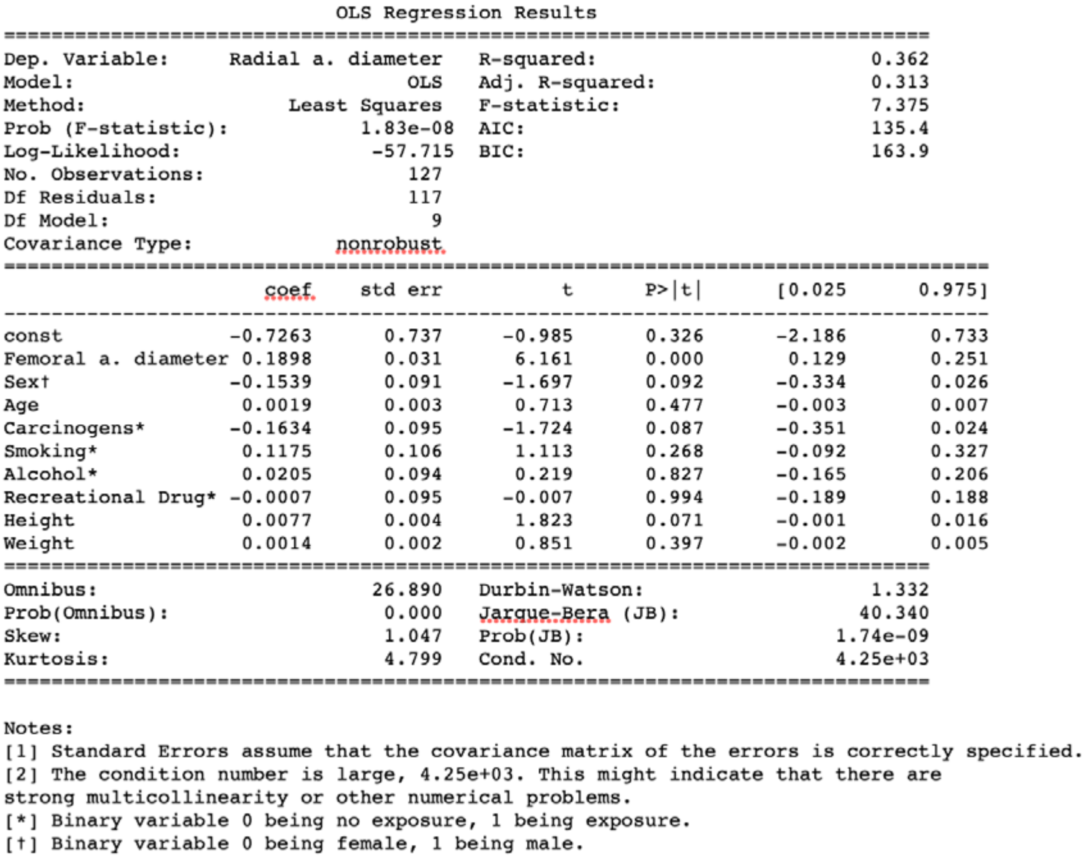


Figure 5. Visualization of random forest classifier model with the model's features and weights. The cell color spectrum, from orange to blue, represents the confidence that a decedent's radial artery is greater than 2.5mm (more orange) or less than 2.5mm (more blue). The Gini index can be seen decreasing further along the forest, thus indicating less variance and improved classification. Conclusively, the plot yields a decision tree for evaluating if the decedent's radial artery is greater than or less than 2.5mm. These data also contained the associated biographic and demographic features (height(cm), carcinogen exposure, smoking history, biological sex, weight(kg), age(years), alcohol use history, and recreation drug use/substance use exposure). When the node's statement is true, one moves to the left to the next node, and false to the right


```
                            OLS Regression Results
==============================================================================
Dep. Variable:      Radial a. diameter   R-squared:                       0.362
Model:                             OLS   Adj. R-squared:                  0.313
Method:                  Least Squares   F-statistic:                     7.375
Prob (F-statistic):           1.83e-08   AIC:                             135.4
Log-Likelihood:                -57.715   BIC:                             163.9
No. Observations:                  127
Df Residuals:                      117
Df Model:                            9
Covariance Type:             nonrobust
===================================================================================
                      coef    std err          t      P>|t|      [0.025      0.975]
-----------------------------------------------------------------------------------
const              -0.7263      0.737     -0.985      0.326      -2.186       0.733
Femoral a. diameter 0.1898      0.031      6.161      0.000       0.129       0.251
Sex†               -0.1539      0.091     -1.697      0.092      -0.334       0.026
Age                 0.0019      0.003      0.713      0.477      -0.003       0.007
Carcinogens*       -0.1634      0.095     -1.724      0.087      -0.351       0.024
Smoking*            0.1175      0.106      1.113      0.268      -0.092       0.327
Alcohol*            0.0205      0.094      0.219      0.827      -0.165       0.206
Recreational Drug* -0.0007      0.095     -0.007      0.994      -0.189       0.188
Height              0.0077      0.004      1.823      0.071      -0.001       0.016
Weight              0.0014      0.002      0.851      0.397      -0.002       0.005
==============================================================================
Omnibus:                       26.890   Durbin-Watson:                   1.332
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               40.340
Skew:                           1.047   Prob(JB):                     1.74e-09
Kurtosis:                       4.799   Cond. No.                     4.25e+03
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 4.25e+03. This might indicate that there are
strong multicollinearity or other numerical problems.
[*] Binary variable 0 being no exposure, 1 being exposure.
[†] Binary variable 0 being female, 1 being male.
```

Figure 6. Results of linear regression model when predicting radial artery diameter from femoral artery diameter and other biographical variables. The linear algorithm reveals the following listed features from most to least significant: femoral artery diameter(mm), height(cm), carcinogen exposure(1 if yes, 0 if no), smoking history(1 if yes, 0 if no), biological sex(1if male, 0 if female), weight(kg), age(years), alcohol exposure(1 if any lifetime alcohol exposure, 0 if none), and recreation drug exposure(1 if any lifetime recreational drug exposure, 0 if none)

4.3. Linear Regression: Another Machine Learning Model

Given the complexity of machine learning algorithm weighting systems and the inability to identify the corresponding numeric weight to features, Figure 6 provides insight into machine learning weighting. *Figure 6* shows the same variables and features passed to a linear algorithm. Though not a direct correlate to the random forest classifier model, the linear algorithm reveals the following listed features from most to least significant: femoral artery diameter, height, carcinogen exposure, biological sex, weight, age, alcohol exposure, and recreation drug exposure. It can be interpreted as for every 1.0mm increase in femoral artery diameter, the radial artery diameter is predicted to increase 0.1898mm while controlling all other variables. Each additional algorithm such as sex, age, etc., create additional variables to manipulate the radial artery dependent variable.

The linear algorithm model supports femoral artery diameter as the strongest correlated, and only significant variable contributing to radial artery diameter, while recreational drug exposure as the weakest correlated. We can surmise similar feature weights when the data is passed to the random forest classifier model. Again, the purpose of Figure 6 is to provide a window to how the computer weighs the importance of the variables and should not be used as a predictive algorithm. The data, methods, and software have been made available on GitHub[6] for free download and use in concordance with the GNU General Public License v3.0.[7]

5. Discussion

Transfemoral artery procedures allow many opportunities for minimally invasive treatment. Prior to the wide adoption of the transfemoral artery procedure technique, open surgeries were the default for all therapies. The impetus for the medical community's conversion to transfemoral artery procedures over open procedures were multiple, including the reduced time in hospital for the patient, decrease in costs, and, most importantly, improved patient outcomes. Complications such as hematoma occurrence, incidence of postoperative infections, and unintended surgical consequences dramatically decreased [20].

This movement from open surgical procedures to transfemoral artery procedures did not come without cost. Technological advancements needed to be made such that the vital instruments could now pass through the arterial space. Procedure and operating rooms needed to be re-organized to accommodate new techniques. And the most difficult step – re-training the given medical workforce – had to be initiated. The gradual change from open surgeries to less invasive procedures has, and still is, successfully occurring to present day. This change has been reflected in the world's improved healthcare administration [20,21].

Now, with the exponential advancements in technology that have permeated all aspects of life including healthcare, another paradigm shift is underway. The movement from transfemoral artery procedures to transradial procedures shows similar promise as the former procedural paradigm shifts. Former studies have shown transradial artery procedures have the potential to replace transfemoral artery procedures in patients who are candidates for transradial access. Multiple publications have shown successful applications in various fields, from cardiology to vascular surgery and interventional radiology.

Taking patient consideration, patients have shown a preference for transradial artery procedures over transfemoral artery procedures. A study by Liu et al showed transradial artery procedures were associated with significantly lower pain scores overall during the procedure, at the access site during the procedure, and in the recovery room compared with transfemoral artery procedures [7].

The difficulty behind wider adoption of transradial artery procedures is the added complexity of ensuring the radial artery has the capacity to support a given procedure. The current standard of care is to utilize extra imaging, such as upper extremity ultrasonography, as well as the Barbeau. Ultrasonography allows for visual assessment of the patency of the vessel while the Barbeau test evaluates for a patent palmar arch should radial artery thrombosis occur [6]. Studies in the past have attempted to bypass the extra imaging by showing multiple correlations between demographic data and radial artery size. In Aykan et al, it was found that radiate artery diameter was correlated with wrist circumference ($r=0.539$, $p<0.001$), height ($r=0.258$, $p<0.001$), weight ($r=0.237$, $p<0.001$), body mass index ($r=0.167$, $p=0.013$), shoe size ($r=0.559$, $p<0.001$), and pulse pressure ($r=-0.161$, $p=0.016$). The right radial artery was larger in men than in women (2.73±0.39 mm vs. 2.15±0.35 mm, $p<0.001$), and smaller in patients with sedentary office work than in physically active outdoor workers (2.42±0.45 mm vs. 2.81±0.37 mm, $p<0.001$) [22].

This study contributes to the possible usefulness of machine learning as an aid to assess the diameter of the radial artery. This provides interventionalists with another tool to assess vascular capacity based on the patient's biographic, demographic, and imaging data. These data would be collected and analyzed regardless of procedure route, thus not requiring any further testing that has traditionally been performed. This continuous pursuit of re-imagining medical testing may lay the groundwork for future research and improve patient outcomes for the broader medical community.

6. Limitations

The authors of the study acknowledge multiple limitations. For one, the small sample size leaves a need for additional testing and larger sample sizes. The study also acknowledges the potential limited ability of a non-contrast CT scan for artery diameter measurements. Finally, the study acknowledges that potential vessel changes can occur post-mortem. However, this study serves to be a template for future machine learning medical analyses and offers a beginning foundation for predicting radial artery diameter based solely on femoral

---

[6] https://github.com/mbrockman1/radial_artery_analysis_paper

[7] https://www.gnu.org/licenses/gpl-3.0.en.html

artery diameter and other parameters. In vivo studies are needed for confirmation of findings

Conflict of Interest

No Conflicts of Interest reported.

Funding Sources

No Financial Gain.

Acknowledgements

This study was supported by Dignity Heath St. Joseph's Medical Center and Banner Desert Medical.

References

[1] Treuting R. Minimally invasive orthopedic surgery: arthroscopy. Ochsner J. 2000; 2: 158-163.
[2] Banta HD. Introduction. Minimally invasive therapy in five European countries: diffusion, effectiveness and cost-effectiveness. Health Policy. 1993; 23: 1-5.
[3] Riskin DJ, Longaker MT, Gertner M, Krummel TM. Innovation in Surgery: A Historical Perspective. Ann Surg. 2006; 244: 686.
[4] Pancholy S, Patel T, Sanghvi K, Thomas M, Patel T. Comparison of door-to-balloon times for primary PCI using transradial versus transfemoral approach. Catheterization and Cardiovascular Interventions. 2010. p. NA-NA.
[5] Iezzi R, Pompili M, Posa A, Annicchiarico E, Garcovich M, Merlino B, et al. Transradial versus Transfemoral Access for Hepatic Chemoembolization: Intrapatient Prospective Single-Center Study. J Vasc Interv Radiol. 2017; 28: 1234-1239.
[6] Fischman AM, Swinburne NC, Patel RS. A Technical Guide Describing the Use of Transradial Access Technique for Endovascular Interventions. Tech Vasc Interv Radiol. 2015; 18: 58-65.
[7] Liu LB, Cedillo MA, Bishay V, Ranade M, Patel RS, Kim E, et al. Patient Experience and Preference in Transradial versus Transfemoral Access during Transarterial Radioembolization: A Randomized Single-Center Trial. J Vasc Interv Radiol. 2019;30: 414-420.
[8] Cooper CJ, El-Shiekh RA, Cohen DJ, Blaesing L, Burket MW, Basu A, et al. Effect of transradial access on quality of life and cost of cardiac catheterization: A randomized comparison. Am Heart J. 1999; 138: 430-436.
[9] Satti SR, Vance AZ, Golwala SN, Eden T. Patient Preference for Transradial Access over Transfemoral Access for Cerebrovascular Procedures. J Vasc Interv Neurol. 2017; 9: 1-5.
[10] Balaban Y, Akbaş MH, Akbaş ML, Özerdem A. Efficacy and Safety of "Coronary Artery Bypass Graft Angiography" with Right Transradial Access versus Left Transradial Access and Femoral Access: a Retrospective Comparative Study. Braz J Cardiovasc Surg. 2019; 34: 48-56.
[11] Amro A, Mansoor K, Amro M, Hirzallah H, Sobeih A, Kusmic D, et al. Transradial Versus Transfemoral Approach for Coronary Angiography in Females with Prior Bypass Surgery. Cureus. 2020; 2: e6797.
[12] Sweid A, Jabbour P. Intra-arterial chemotherapy for retinoblastoma: transradial and transfemoral approach. J Neurointerv Surg. 2020;12: 828.
[13] Bishay VL, Biederman DM, Ward TJ, van der Bom IMJ, Patel RS, Kim E, et al. Transradial Approach for Hepatic Radioembolization: Initial Results and Technique. AJR Am J Roentgenol. 2016; 207: 1112-1121.
[14] Thakor AS, Alshammari MT, Liu DM, Chung J, Ho SGF, Legiehn GM, et al. Transradial Access for Interventional Radiology: Single-Centre Procedural and Clinical Outcome Analysis. Can Assoc Radiol J. 2017; 68: 318-327.
[15] New Mexico Decedent Image Database - Welcome Home. [cited 1 May 2021]. Available: http://nmdid.unm.edu/.
[16] Horos Project - Free DICOM Medical Image Viewer. [cited 1 May 2021]. Available: https://horosproject.org/.
[17] Welcome to Python.org. [cited 1 May 2021]. Available: https://www.python.org/.
[18] Jupyter and the future of IPython — IPython. [cited 1 May 2021]. Available: https://ipython.org/.
[19] scikit-learn. [cited 1 May 2021]. Available: https://scikit-learn.org/stable/index.html.
[20] Gautschi OP, Stienen MN, Corniola MV, Schaller K. [Minimal invasive surgery: historical review, current status and perspective]. Praxis. 2014; 103: 1323-1329.
[21] Biondi A, Grosso G, Mistretta A, Marventano S, Toscano C, Drago F, et al. Laparoscopic vs . open approach for colorectal cancer: evolution over time of minimal invasive surgery. BMC Surg. 2013; 13: 1-6.
[22] Aykan AÇ, Hatem E, Kalaycıoğlu E, Altıntaş Aykan D, Gökdeniz T, Arslan AO, et al. Prediction of radial artery diameter in candidates for transradial coronary angiography: Is occupation a factor? Turk Kardiyol Dern Ars. 2015; 43: 450-456.