An Assessment of Knee Flexion in Lateral Knee X-rays

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Purpose: *Patient positioning plays a crucial role in the field of radiology. Lateral knee X-rays are a type of image that often has incorrect positioning of the angle of knee flexion. The ideal range is between 20 and 30 degrees. The goal of this study was to assess the angle of knee flexion at two different locations in a single hospital system while determining if several variables influence the angle.*

Method: *This study is a retrospective chart review that assessed the angle of knee flexion in patients 18 years or older that underwent a lateral-mediolateral knee X-ray taken at an urgent care center and a general diagnostic center of a hospital within the same system between March 1 and December 1, 2021. Variables including age, sex, BMI, technologist, and location were collected from these patients' charts and evaluated. MRI information was gathered for patients who underwent an MRI within 30 days of a lateral knee X-ray. The research team assessed effusions reported on X-ray compared to effusions reported on MRI for these patients.*

Results: *Among patients included in the study (n = 665) the average angle of knee flexion was 51.28 degrees. Age, sex, BMI, and location were not significantly associated with the mean angle of knee flexion with p-values of 0.63, 0.13, 0.55, and 0.15 respectively. The radiology technologist taking the image did have an association with the angle of knee flexion with a p-value of 0.001. Differences in the mean angle of knee flexion between the groups of X-rays with effusions reported compared to the groups of X-rays where effusions were not reported but found on MRI resulted in a p-value of 0.83.*

Conclusions: *The technologist taking the image was the only variable of this study that had a significant difference in mean angle of knee flexion. Additional studies are needed to determine what technologist factors are most important in determining the angle of knee flexion. Using MRI information to evaluate if effusions were not reported due to the angle of knee flexion was limited in this study due to small sample size.*

Keywords: *radiological positioning; angle of knee flexion; radiology; X-ray interpretation*

INTRODUCTION

Radiology plays an important role in the care of patients. Physicians often turn to imaging for assistance with diagnosis and treatment. There are many factors that go into the production and interpretation of a radiological study. The radiology technologists have a crucial part in the production of these images. These individuals are tasked with providing radiologists with the images to diagnose patients. Factors that need to be considered by the radiology technologist include type of image, body part being imaged, flexion, extension, rotation, comfort, ability of the patient, and much more. Some of the images, such as the lateral-mediolateral knee X-ray, can be difficult to obtain by the technologists. The difficulty with this particular image is positioning. The knee needs to be flexed, rotated, and aligned properly.[1]

When evaluating a lateral-mediolateral knee X-ray, the quality of the image is of high importance. Specifically, the angle of knee flexion should be between 20 and 30 degrees.[2,3] According to studies assessing different knee anatomy,[4,5] lateral knee imaging rotated as little as 5 degrees off-axis from true lateral can have a significant effect including misreading important pathology. In addition to rotation, when the knee is hyperflexed, it can decrease the view of the suprapatellar fat pads causing decreased visualization of effusions and possible missed pathology.[6]

This project aimed to evaluate the lateral-mediolateral knee X-rays at a healthcare center. The research team looked to assess the angles of knee flexion as well as the possible effects of age, sex, BMI, technologist taking the image, and location had on the angle of flexion. The team also attempted to compare X-ray and MRI reports to assess whether knee effusions could be underreported due to the angle of knee flexion.

METHODS

This study retrospectively collected data from patients' charts who were 18 or older and underwent a lateral-mediolateral knee X-ray taken at Munson Medical Center and Foster Family Community Health Center in Traverse City, Michigan, between March 1, 2021 and December 1, 2021. Patients with both knees imaged had information collected on both images and were then randomized with a random number generator to only include either their left or right knee. This prevented any 'double counting' of any patient or variable. Only patients with BMI included in their chart were included for the BMI analysis. Only BMI measurements at the time of X-ray were included. The BMI variable was filtered and divided into categories BMI ≤ 18.5, 18.6–24.9, 25–29.9, 30–34.9, and ≥35. These ranges were chosen because they are the standard BMI categories indicating underweight, normal weight, overweight, obese, and morbidly (extremely) obese. The age variable was filtered and divided into categories 18–29, 30–39, 40–49, 50–59, 60–69, 70–79, and 80+. Information on the angle of knee flexion, age, sex, BMI, technologist, and location was collected. F-tests were used to determine if equal variances could be assumed for sex and location. Bartlett's tests of equal variances were used to determine if equal variances could be assumed for age, BMI, and technologists. T-tests were used to assess differences of means for sex, location, and effusions reported. ANOVA tests were used to determine mean differences for age and BMI. A Brown-Forsythe test was used to determine mean differences for technologists. The angle of knee flexion was measured by a single medical student on the team who was instructed on proper technique by a radiologist in order to assure consistency in measurement. A radiology reading application, Inteleconnect, was used to measure the angle of knee flexion as seen in Fig. (1). The angle shown in Fig. (1) was recorded and its supplementary angle was calculated by taking the measured angle and subtracting it from 180 degrees. The supplementary angle was used for the purposes of this study. To decrease chance of bias in measurement, the document used to collect the angle of knee flexion data was separate from the document used to collect variable information. Any patient identifying information was kept on a separate, password-protected spreadsheet, and each patient was assigned a unique patient identifying number.

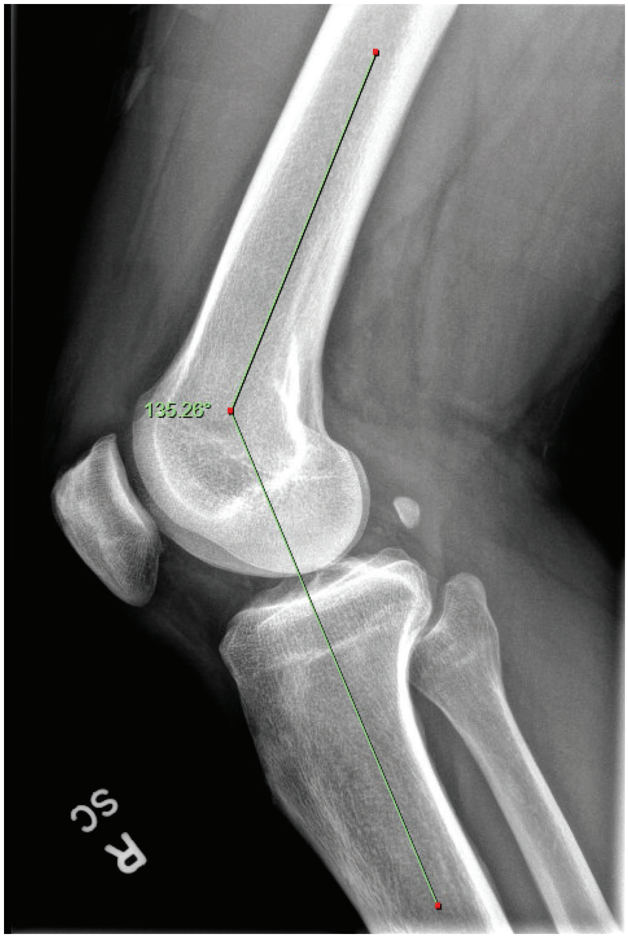

Figure 1. Measuring the angle of knee flexion. Example of the radiology application measurement on a lateral knee X-ray. The green line indicates the angle of knee flexion with the value calculated through the application.

MRI information that followed a lateral-mediolateral knee X-ray within 30 days or less was also collected. The research team attempted to evaluate if effusions were underreported on X-rays due to improper angle of knee flexion by comparing them to the reports of MRIs on the same patient. The patients who had effusions reported on MRI but not X-ray were considered to have effusions 'missed' on X-ray. The patients who had effusions reported on X-ray and MRI were considered to have the effusion properly reported. The patients who did not have effusions reported on either X-ray or MRI were considered to be effusion-free and excluded from further analysis. An F-test was used to determine if equal variances could be assumed for reported effusions. A T-test was used to assess differences of means between the categories of 'missed' effusions to the properly reported effusions.

RESULTS

For this study, 665 patients were found to fit the inclusion criteria. Of these 665 patients, 105 had both knees imaged. For these patients, only one knee was selected to be included by a random number generator as mentioned in the methods section. Summaries for the variable's demographics can be seen in the appendix Tables (A1–A3).

Looking at the angle of knee flexion for all patients measured, there was a range of 12.54–89.79 degrees with a mean angle of 51.28 degrees and a median of 51.27 degrees. The summary statistics for the angle of knee flexion can be seen in the appendix in Table A1. See Fig. (2) for the distribution of the angle of knee flexion.

For age, variance testing showed a *p*-value of 0.68 meaning equal variance could be assumed. Statistical testing revealed that there was not a statistically significant difference in the mean angle of knee flexion between age groups $p = 0.63$. Refer to Table 1 for age group information.

For male sex versus female sex, variance testing showed a *p*-value of 0.05 meaning equal variances could not be assumed. Statistical testing resulted in a *p*-value of 0.13 meaning there was no statistically significant difference between sex and mean angle of knee flexion. Refer to Table 2 for sex group information.

For BMI, 296 patients were included in the statistical analysis. There were 396 patients who did not have BMI included in their charts. Variance testing showed a *p*-value of 0.51 meaning equal variance could be assumed. Statistical testing revealed that there was not a statistically significant difference in the mean angle of knee flexion between BMI groups $p = 0.76$. Refer to Table 3 for BMI group information.

For analysis of technologists taking the image, there were 43 technologists that took images. For the purpose of this variable assessment, only the technologists with 10 or more measurements were considered, resulting in analysis of 12 technologists. Variance testing showed a *p*-value of 0.00024 meaning equal variance could not be assumed. Statistical testing resulted in a *p*-value of 0.001 meaning that there was a statistically significant difference in the mean angle of knee flexion between technologists. Refer to Table 4 for technologist measurement information.

With respect to the location that the images were taken at, variance testing showed a *p*-value of 0.33 meaning that equal variances could be assumed.

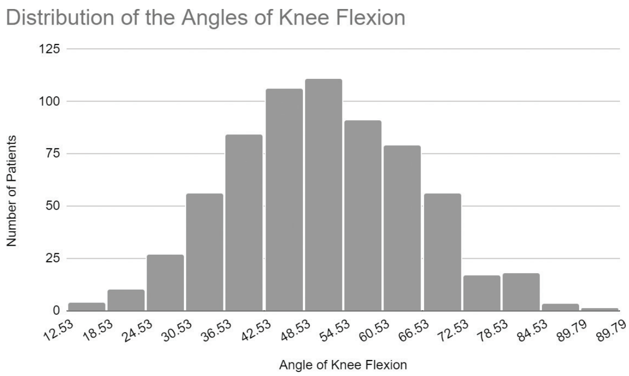

Figure 2. Distribution of the angles of knee flexion. Histogram of the angle of knee flexion of all measured patients.

Table 1. Age analysis. Variable analysis of age group on mean angle of knee flexion. Differences in mean $p = 0.63$

Age group	Mean angle of knee flexion (in degrees)	Standard deviation
18–29	48.11	16.28
30–39	49.02	15.14
40–49	50.47	12.80
50–59	51.52	13.05
60–69	51.79	13.49
70–79	51.34	13.85
80+	53.64	14.33

Table 2. Sex analysis. Variable analysis of sex on mean angle of knee flexion. Differences in mean $p = 0.13$.

Sex group	Mean angle of knee flexion (in degrees)	Standard deviation
Male	50.36	14.55
Female	52.02	13.09

Table 3. BMI analysis. Variable analysis of BMI on mean angle of knee flexion. Differences in mean $p = 0.55$.

BMI group	Mean angle of knee flexion (in degrees)	Standard deviation
<18.5	59.10	22.21
18.6–24.9	49.87	14.74
25–29.9	52.91	15.28
30–34.9	50.53	13.56
>35	51.90	13.45

Table 4. Technologist analysis. Analysis of technologists on mean angle of knee flexion. Differences in mean $p = 0.001$.

Technologist	Mean angle of knee flexion (in degrees)	Standard deviation
Tech 1	60.43	11.90
Tech 2	50.47	13.08
Tech 3	62.50	10.96
Tech 5	38.49	10.74
Tech 7	53.84	15.55
Tech 9	54.29	14.72
Tech 11	51.27	9.63
Tech 13	49.79	13.05
Tech 14	41.30	9.90
Tech 15	51.67	15.91
Tech 18	46.32	8.07
Tech 19	51.39	10.19

Table 5. Location analysis. Variable analysis of location on mean angle of knee flexion. Differences in mean $p = 0.15$.

Location	Mean angle of knee flexion (in degrees)	Standard deviation
Hospital	52.20	13.31
Urgent care	50.63	14.04

Statistical testing revealed a *p*-value of 0.15 meaning there was no statistically significant difference between locations and mean angle of knee flexion. Refer to Table 5 for location information.

When comparing effusion reporting with MRI and X-ray, there were 13 patients who fit the criteria of 'missed' effusions and 21 patients who fit the criteria of reported effusions. Comparing the angle of knee flexion in groups of effusions reported on both X-ray and MRI (reported effusions) to effusions reported on MRI but not X-ray ('missed' effusions), variance testing showed a *p*-value of 0.29 meaning that equal variances could be assumed. Statistical testing resulted in a *p*-value of 0.83 meaning there was no statistically significant difference between reported effusion groups and mean angle of knee flexion. Refer to Table 6 for reported effusion group information.

DISCUSSION

Overall, the angle of knee flexion in these patients showed a distribution along a standard curve with the mean falling well above the accepted angle 20–30 degrees. This could be due to several factors, only some of which were measured in this study. Since this study found the radiology technologist measurements to have a statistically significant difference between mean angles measured, the variables involving the technologists are likely to have the largest impact. Some variables that were not included in this study that could be researched further include technologist age, training level, amount of work experience, and areas of imaging experience.

Table 6. Effusion analysis. Effusions reported on MRI but not X-ray considered 'missed' while effusions reported on both X-ray and MRI were reported appropriately. Differences in mean $p = 0.83$.

Effusion report	Mean angle of knee flexion (in degrees)	Standard deviation
Effusion 'Missed' on X-ray	52.00	15.41
Effusion reported on X-ray	51.00	11.88

None of the possible patient-centered variables (age, sex, and BMI) measured in this study were statistically significant. One possible explanation for this is patient willingness to participate in their care. Most patients will position themselves however the technologist asks them to do if they are able. Some of these variables were considering that the patient might not be able to flex their knee to the proper angle due to BMI or age, for example, but these did not seem to be a factor to a significant degree.

The final variable assessed in this study was location. This did not appear to have a significant association to the angle of knee flexion either. Possible explanations for this would be that both the urgent care and hospital are in the same hospital network within the same city. They use the same training systems for technologists. In addition to this, some technologists had recorded images at both locations. Though this may introduce some bias, this variable was mainly intended to assess differences in equipment and procedure at each location. It would be useful for future studies to assess these variables at different facilities in several different hospital systems and cities. It is likely that the results will be similar to this study with the technologist having the largest impact on angle of knee flexion with other variables having minimal, if any, significance. This study is generalizable because it includes a large sample size, has a variety of ages and BMIs with a ratio of sexes being 1.33/1. Though ethnicity was not included in this study, it is unlikely that it would impact measurements.

There are several limitations to consider for this study. Firstly, errors could have been made in measurement of the angles of knee flexion. This error was limited by having a single researcher measure all of the angles and to have this researcher trained on measurements of this angle by a radiologist. Secondly, BMI was not recorded in all the patient's charts, so some of the information regarding this variable could be biased to patients who were hospitalized at one point in time resulting in this measurement being in the chart. There are two primary limitations to the evaluation of effusions between X-ray and MRI. There was a small number of patients who had an MRI follow-up within 30 days with reported effusions – a total of 21 in the group where effusions were reported on both X-ray and MRI and 13 in the group where it was not reported on X-ray but was reported on MRI. This is a very small sample size, and it does not have the power to determine significance. In addition to this, effusions reported on X-ray can be very subjective to the radiologist dictating the report and may not be reported if the radiologist does not determine the effusion to be of significance.

Some considerations to take away from this study are that the angle of knee flexion varied from technologist to technologist, but overall, the knee joint was hyperflexed. A question that needs to be researched further is 'Does the angle of knee flexion matter clinically?' Theoretically, it has been taught that the angle of flexion is important to fully visualize certain anatomy and pathologies. However, further research needs to be conducted as to if knee flexion influences a radiologist's interpretation of these images, and if so, to what degree. Other future research can be directed toward correcting the discrepancies in knee flexion angles. Creating a tool that technologists can use to quickly and effectively position the patient's knee to the appropriate angle could be implemented. In addition to this, refresher courses could be implemented into continuing education training for radiologic technologists to remind them on important positioning as well as common positioning errors.

CONCLUSION

According to prior research and radiology literature, patient positioning plays a crucial part of producing quality images for radiologists to read. Errors in positioning can lead to images of poor quality and possibly missed pathologies. In lateral knee X-rays, rotation and flexion of the knee are two critical components in producing the image. The research team set out to assess the angle of knee flexion in images produced at two locations in a large rural health system. After analysis, it was found that the angle of knee flexion was significantly different from the ideal range of 20–30 degrees. Several variables were measured to evaluate possible correlations for this discrepancy in angles. Of these variables, the radiology technologist taking the image was the only variable that had a significant difference in the mean angle of knee flexion. Further research looking into whether the angle of knee flexion influences the report generated by the radiologist, possibly with 'missed diagnoses', such as effusions, needs to be performed. In addition to this, a tool to allow radiology technologists quick and accurate measurements of knee flexion angle could be explored along with a refresher course on positioning.

Institutional Review Board Statement

Our Institutional Review Board approved the review of the patients' charts in this study and waived the need for consent.

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Conflicts of Interest

None. The authors were not compensated or funded in any way for the preparation of this manuscript. This study has not been submitted elsewhere. We understand and agree that if the manuscript is accepted for publication, copyright in the article, including the right to reproduce the article in all forms and media, shall be assigned to the publisher.

REFERENCES

1. Martensen KM. A consistent method to produce lateral knee radiographs. Radiol Technol 1990; 62(1):24–7.

2. Tai AW, Alparslan HL, Townsend BA, Oei TN, Govindarajulu US, Aliabadi P, et al. Accuracy of cross-table lateral knee radiography for evaluation of joint effusions. Am J Roentgenol 2009; 193(4):W339–44. doi: 10.2214/AJR.09.2562

3. Thakur AJ. Knee. Strategic Radiographic positioning. Philadelphia: Wolters Kluwer Health; 2010.

4. Ziegler CG, Fulkerson JP. & Edgar C. Radiographic reference points are inaccurate with and without a true lateral

radiograph: The importance of anatomy in medial patellofemoral ligament reconstruction. Am J Sports Med 2016; 44(1):133–42. doi: 10.1177/0363546515611652
5. Huddleston HP, Redondo ML, Cregar WM, Christian DR, Hannon CP, Yanke AB. The Effect of Aberrant Rotation on Radiographic Patellar Height Measurement Using Canton-Deschamps Index: A Cadaveric Analysis. J Knee Surg 2023;36(3):254–260. doi: 10.1055/s-0041-1731720.
6. Martensen KM. Radiographic image analysis. 2nd ed. Philadelphia: Elsevier Saunders; 2006, pp. 317–24.

APPENDIX

Table A1. Study demographics. Highlighting the summary statistics of angle of knee flexion and variables patient age and BMI.

Statistical measurment	Angle of knee flexion (in degrees)	Patient age	BMI
Mean	51.28	61.06	30.84
Median	51.27	64	29.7
Standard deviation	13.73	14.82	7.17
Range	12.53–89.79	18–95	15.2–67.6

Table A2. Patient sex demographics. Study demographics of patient population regarding the variable of sex.

Sex	Number of patients
Male	378
Female	285
Male:Female ratio	1.33/1

Table A3. Location demographics. Study demographics regarding the variable of location.

Location	Number of patients
Hospital	286
Urgent care	377
Hospital: Urgent care ratio	0.76/1