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IMPACT OF RADIOLOGICAL PELVIMETRY AND THE EFFECT OF PELVIC BONE ANATOMY ON INGUINAL HERNIA

Syamala Sai Vennela[1], Sanjeeva Raju Kunche[2], Sendhilnathan[3], Sampathkumar Poral[4]

[1]Postgraduate, Department of Surgery, AVMC, Puducherry, India
[2]Professor, Department of Surgery, AVMC, Puducherry, India
[3]Associate Professor, Department of Surgery, AVMC, Puducherry, India
[4]Professor and HOD, Department of Surgery, AVMC, Puducherry, India

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Corresponding Author:
Dr. Syamala Sai Vennela,
Email: syamalasaivennela@gmail.com

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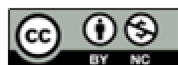

ABSTRACT

Background: In relation to inguinal hernias, affecting millions of people globally, the role of pelvic bone structure in hernia formation has remained clear . However, advancements in radiological imaging have made it possible to more accurately assess the shape of the pelvic bone. A brand-new objective and quantitative tool to analyze the anatomical aspects of hernia development is now being tested: radiological pelvimetry. Looking at the relationship between pelvic bone structure and inguinal hernias, this study investigated the use of radiological measurements such as the Radoievitch angle and Ami's line. Comparing individuals with and without inguinal hernias, they found that the bone structure is different in the two cases, but were also looking at the significance of a low-lying pubic tubercle in the development of hernias and whether it could be used to predict who is at a higher risk of hernias and, as a preoperative and surgical planning tool. **Materials and Methods:** When investigating inguinal hernias, a hospital-based case-control study involving 110 participants, half of whom had a clinically confirmed inguinal hernia and half of whom were age-:and sex-matched controls without hernias, used standardized supine anteroposterior pelvic radiography on all participants. To measure the Radoievitch angle, the researchers calculated the angle between the sacral long axis and a horizontal reference line at the sacral promontory, and measured the length of line, from Adam's anterior superior iliac spine to the pubic tubercle, and also considered the pubic tubercle as low-lying if its distance from the interspinous reference line was greater than 7.5 cm. Demographic information such as age, sex, height, weight and BMI was also collected, and using SPSS version 21 the researchers found independent predictors. **Result:** The study demonstrated a significantly higher mean. Radoievitch angle, measuring 42.8 degrees compared to the control group, and 40.9 degrees, and this difference is highly significant, when examining the physical characteristics of patients with hernias. Another measure of inguinal ligament length, Ami’s line, was found to be significantly longer in the hernia group, and measuring 8.4 cm to the 7.3 cm measured in the control group, a difference that is less than 0.001. An astonishing 61.8 percent of hernia cases had a low-lying pubic tubercle, as opposed to the 32.7 percent of the control group that did. Pantaloon and bilateral hernias presented with higher pelvimetric measures, and multivariate logistic regression found Radoievitch angle, Ami’s line and low-lying pubic tubercle to be independent risk factors for developing inguinal hernias. **Conclusion:** Radiological pelvimetry is a useful tool, when evaluating a patient for an inguinal hernia. Measuring the structure of the pelvic bone, it can predict the development and type of hernia. The Radoievitch angle, Ami's line length, and pubic tubercle position are all independent markers that suggest the possibility of a hernia. As a simple, non-invasive procedure, radiological pelvimetry has proven to be a reliable way to classify the anatomical risk, preoperatively. Preoperative pelvic examination is also capable of boosting risk assessment in standard diagnostic routines and enabling early intervention in high-risk cases, along with direction for surgical methods that are finely tuned to the patient’s anatomy.

INTRODUCTION

Regarding inguinal hernias, epidemiological studies tell us that 27% of men and 3% of women will be diagnosed with inguinal hernia during their lifetime. An inguinal hernia is essentially a defect in the lower part of the abdominal wall near the inguinal canal, where the contents of the abdominal cavity bulge through the defect. If left untreated, this condition can cause intense pain, impair normal function, and, in the worst case, lead to strangulation, which is a life-threatening emergency that requires emergency surgery.[1,2]

Smoking, chronic obstructive pulmonary disease, obesity, and connective tissue disorders all contribute to the risk of hernia formation and people who have undergone previous abdominal surgery, as well as the elderly, are also at greater risk, but the exact reasons why still require further study. Well-known improvements in surgical techniques and tension-free mesh repairs, however, have greatly reduced the rate of recurrence. It's clear that this disease multi-factorial issue has mechanical, biological, and anatomical angles contributing to its pathogenesis.[3,4]

Men tend to be significantly more prone to inguinal hernias than women, in fact, eight to ten times so. In adults, the problem often peaks between 75 to 80 years old. It's also found in children at a high prevalence under five years of age.[5]

Interestingly, right-sided hernias, where the protrusion occurs from the right side, and the tendency of hernias in affected individuals to cross over from one side to the other (bilateral) also suggest the role of biomechanical elements, or issues that have to do with the strength and movement capacity of our joints. Researchers have looked at pelvic bone shapes and anatomical differences at the inguinal area, showing that these to have a particular knack for increasing hernia risk. Medical tests that measure the dimensions and spatial orientation of the pelvic bones can be used in conjunction with ultrasound assessments. When looking at the mechanics of the myopectineal orifice and the posterior inguinal wall, radiological parameters like the Radoievitch angle and Ami's line can tell us something about the variation in pelvic structure, and how it affects the forces acting on the inguinal area. The anatomy of the inguinal canal may be affected by the low position of the pubic tubercle, seen via radiological examination, and affects the muscle support around the deep inguinal ring, as well as the shutter mechanism.[6,7]

Pelvimetry has been found to be a possible way to identify anatomical risk factors, although unfortunately, its link to inguinal hernia occurrence and features is still a mystery, yet to be studied systematically. Traditionally, in hernia research the main variables considered were age, BMI and comorbidities, with pelvic structure being somewhat neglected. Well-known inguinal hernia anatomical markers are really just the tip of the iceberg, but we can use the results of radiological pelvimetry to get started in closing the knowledge gap on hernia pathophysiology, and could potentially find objective markers that affect the way clinicians decide on treatment.[8-10]

This study investigated whether we can tell inguinal hernia patients apart from those without hernias, by looking at the angles, lines and curves created by the pelvic bones. In particular, we tested Radoievitch angle, Ami's line length and the location of the pubic tubercle as independent markers of hernia risk.

MATERIALS AND METHODS

Study Design and Setting

When conducting a prospective hospital-based case-control research in the Department of General Surgery and Department of Radiology at Aarupadai Veedu Medical College and Hospital in Puducherry, India, from February 2024 through February 2026, a tertiary care hospital with different patient flows was the backdrop. The study had the blessing of the hospital's Institutional Ethics Committee, and all participants provided informed consent in their native language, after being completely explained the purpose, methods and risks of the study.

Out of 110 participants, 55 had clinically confirmed inguinal hernias, and were matched with 55 people who didn't have hernias, of the same age and sex. The age range of the participants was between 30 and 70. The people with hernias, all came to the General Surgery department with a bulge in the groin area that gets bigger when they stand up, strain themselves, or cough, and weren't admitted to hospital for any other reason. Those without hernias were admitted for routine tests or minor surgery that isn't related to hernias, and were carefully matched to the people with hernias by age (within five years) and sex.

The case group consisted of people who were 30-70 years old, had a confirmed clinical diagnosis of a primary inguinal hernia that was verified by a physical examination, a signed consent form, and a radiological examination. The control group had to be aged 30-70, be free of inguinal hernia, have no major problems in the pelvic area, need a pelvic scan for a different reason, and be able to give informed consent. The study didn't include anyone who had broken bones in the pelvis, significant trauma or deformities that affect the shape of the pelvis, past surgery that might have altered the anatomy, hernias that can't be pushed back into the abdominal cavity, strangulated or blocked hernias that require emergency treatment, or associated conditions like hydrocele or undescended testis in men. We used a pre-determined case recording form and after obtaining informed consent, recorded each participant's demographic information, full age, sex, occupation and any relevant medical history, when collecting data. Participants were measured in lightweight clothing, without shoes. We used a calibrated stadiometer to measure height to the

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nearest 0.1 centimeters and a digital scale to measure weight to the nearest 0.5 kilograms. Body mass index was calculated by dividing the weight in kilograms by the square of the height in meters.
Clinical data for hernia patients, including the location of the hernia, type of hernia and clinical history, was also collected and symptoms associated with hernia, how long the hernia has been present, and previous repair history were of particular interest. All participants underwent supine anteroposterior pelvic radiography using uniform exposure settings. Our trained technicians took the radiographs with the patient lying down on the table, their legs outstretched and their feet apart. The centre of the X-ray beam was placed at the top of the pelvic bones. To avoid any bias, the experienced radiologists who evaluated the images had no knowledge of the participant's group status, case or control.
A line running along the long axis of the sacrum and a horizontal reference line at the sacral promontory were used to measure the Radoievitch angle, a measure of pelvic tilt. The length of the Ami's line, measuring the inguinal ligament from the top of the pelvic bone to the pubic tubercle, and the distance of the pubic tubercle from the interspinous reference line were also used in the analysis.

Methods of Statistics

We used SPSS 21, courtesy of IBM Corporation in Armonk, New York, to crunch the numbers, when we looked at the data. Descriptive statistics for all our variables were calculated, and for the continuous ones like age, body measurements, and pelvic measurements, we used the mean and standard deviation. Coming running over through the data, we found that gender, low-lying pubic tubercle, and the type of hernia were best expressed as frequencies and percentages. We checked if the continuous variables were normally distributed using the Shapiro-Wilk test, and then used the independent samples t-test for those that were, and the Mann-Whitney U test for those that weren't, to compare the case and control groups. Group-based variables were compared using the chi-square test of independence.
Sex based differences in pelvic measurements were analysed, breaking down the data by gender, and used one-way ANOVA to compare the pelvic measurements of indirect, direct and pantaloon hernias. The Radoievitch angle and Ami's line measurements, were investigated using Pearson correlation analysis. The multivariate logistic regression, with the dependent variable being hernia or not, allowed us to find independent predictors, and we adjusted for age and sex. The independent variables included Radoievitch angle, Ami's line, and the status of a low-lying pubic tubercle, and for each of these, we calculated odds ratios and their 95% confidence intervals, and considered the test to be significant if the p-value was less than 0.05.

RESULTS

Examine Population and Demographics: The female hernia patients had higher levels of Radoievitch angle, pelvic inclination, line measures and mean Ami's angle. This sexual difference in sexual gender is expected. In terms of gender interaction, BMI showed the most gender variance.
Although not statistically significant, but it could be inferred, age 50.42 versus 49.42, gender distributions are different between the control and the case group, where in the case group males accounted for 83.6% and females 16.4%, in the control group the gender ratio is 61.8% men and 38.2% women. As for the difference of p=0.019, Inguinal hernias are more common in males than in females, which is a statistically significant difference. The mean height and weight were measured at 167.3, and 74.2 kilograms in cases and 168.1 and 74.8 kilograms in controls, which gave a probability value of p=0.510. Both groups also shared a very similar BMI, which measured at 25.02, and 25.71. This indicates that the body mass index didn't affect the pelvic measurements, and in fact did not differ.
Radoievitch angles were at 42.8 and 40.9 degrees in the case and control groups respectively, had a p-value of less than.001, showing that inguinal hernia patients have a more vertical pelvis. The reason behind this is possibly their pelvic inclination which may weaken the posterior inguinal wall, In the line measures 8.4 centimeters belonged to the case group, in contrast to 7.3 centimeters for the control group, with p-value of less than.001. Inguinal hernia patients have extended inguinal ligaments that, may lead to widening of the inguinal region and dislodge the back wall of the inguinal canal. The functions of the dynamic shutter mechanism could also be lessened by the longer Ami's line and inguinal ligament. The female hernia patients' pelvimetric measures were notably different from those in males, higher Radoievitch angles, pelvic inclinations, line measures, and mean Ami's angles. This difference between sexes was as expected, but BMI showed the biggest difference. Male patients had a significantly larger mean Radoievitch angle, 43.2 degrees, compared to 41.1 degrees in controls, when comparing hernia patients to non-hernia patients. Male hernia cases had much longer Ami's line measures, 8.6 centimeters, than their male counterparts in the control group, who had measures of 7.4 centimeters. Women in the hernia group also had higher Radoievitch angles and longer Ami's lines, 42.1 degrees and 7.9 centimeters respectively, in comparison to the control group which had 7.1 centimeters. This difference between the sexes may be the reason why men are more likely to develop inguinal hernias.
In the study, a significantly larger proportion of hernia patients had a low-lying pubic tubercle, >7.5 centimeters from the interspinous line. Coming in at 61.8% in the case group, compared to 32.7% in the

control group, the position of the pubic tubercle can be considered an important anatomical indicator.

The hernia patients with low-lying pubic tubercles showed significant differences in mean pelvimetric measurements, which were higher than those patients who had normal pubic tubercle positions, indicating anatomical modifications on the pelvic bone are affecting the incidence hernias.

44.1 Degrees and 8.9 centimeters for low lying tubercles, compared to 40.5 degrees and 7.2 centimeters for pubic tubercles in the normal position. The findings also show increased amplitudes and angles, however these were significant. Rite-sided inguinal hernias accounted for 50.9% of all hernias and happened most frequently. A distribution pattern that is in line with epidemiological trends is observed, when comparing unilateral and bilateral inguinal hernias. Pelvic measurements of patients with bilateral hernias showed a continuous increase in anatomical parameters, in contrast to those with unilateral hernias. The mean Radoievitch angles were 42.3 degrees and 44.5 degrees for unilateral and bilateral hernias respectively, and was significantly different at $p = 0.007$. The same difference is observed in Ami's line measurements, with bilateral hernias having a mean length of 8.8 centimeters, outshining the 8.1 centimeters found for unilateral hernias with $p = 0.012$. Consequently, these results indicate a more marked anatomical deformity in bilateral hernias.

The most common kind of hernia is the indirect hernia, which is seen in 56.4% of cases, followed by direct inguinal hernias in 32.7% of cases and pantaloon hernias which are a combination of both, appearing in 10.9% of cases. These sorts of hernias correspondingly saw an increase in pelvic measures. The average Radoievitch angles for hernia types were 41.5 degrees for direct, 42.9 degrees for indirect and 45.2 degrees for pantaloon and were significant for each. Likewise, the mean length of Ami's line were 7.6 centimeters for direct hernias, 8.5 centimeters for indirect and 9.1 centimeters for pantaloon hernias, all differences were found to be significant. In both cases, anatomical seriousness and clinical symptoms become progressively more severe as the kind of hernia becomes more severe.

Pearson's correlation analysis showed a significant positive correlation between Radoievitch angle and Ami's line length at $r = 0.68$ and $p < 0.001$, showing that both are growing together, rather than being two separate features. The intensity of the relationship between these two parameters suggests that steeper pelvic inclination is accompanied by lengthier inguinal ligaments, and so, these are being looked at as complementary aspects of pelvic anatomical variation. When looking at the development of inguinal hernias, Radoievitch angle has been found to be a highly significant predictor, with each degree rise in angle increasing the risk of hernia by a 32% chance (odds ratio of 1.32, with a 95% CI of 1.15 to 1.51 and a p-value less than 0.001. Adjusting for demographic factors didn't change the picture much. Coming from a different angle, the length of Ami's line also was found to be a predictor for hernias, with a centimeter-by-centimeter increase in the measurement, and lifting the odds of a hernia by 43 percent, to a ratio of 1.43, with a 95% CI of 1.22 to 1.68 and a p-value of less than 0.001, and still significant when you take into account demographic differences.

Now, low-lying pubic tubercles have been shown to be strongly linked to the development of inguinal hernias, almost doubling the risk, with a ratio of 2.18, and a 95% CI of 1.35 to 3.52, and a p-value of 0.002, and the link stays even after we factor out the influence of age and sex.

Well-known, when looking at the three pelvimetric characteristics together in a single analysis, we see that each of them is a predictor for hernias, and the relationship is so strong that it wasn't diminished when we adjusted for age and sex.

Table 1: Demographic and Anthropometric Characteristics of Study Participants

Variable	Cases (n=55)	Controls (n=55)	p-value
Age, years	49.42 ± 12.21	50.42 ± 10.90	0.651
Male gender, n (%)	46 (83.6%)	34 (61.8%)	0.019*
Height, cm	167.3 ± 8.4	168.1 ± 7.9	0.512
Weight, kg	74.2 ± 9.3	74.8 ± 8.7	0.623
BMI, kg/m²	25.02 ± 5.11	25.71 ± 4.52	0.458

* $p < 0.05$; Data expressed as mean ± standard deviation unless otherwise noted

Table 2: Radiological Pelvimetry Measurements Between Case and Control Groups

Pelvimetric Parameter	Cases (n=55)	Controls (n=55)	p-value
Radoievitch angle, degrees	42.8 ± 2.3	40.9 ± 2.4	< 0.001***
Ami's line, cm	8.4 ± 1.0	7.3 ± 1.1	< 0.001***
Low-lying pubic tubercle, n (%)	34 (61.8%)	18 (32.7%)	0.002**

Table 3: Multivariate Logistic Regression Analysis - Independent Predictors of Inguinal Hernia Development

Variable	OR	95% CI	p-value	Sig.
Radoievitch angle (per 1°)	1.32	1.15-1.51	< 0.001	***
Ami's line (per 1 cm)	1.43	1.22-1.68	< 0.001	***
Low-lying pubic tubercle (Yes vs No)	2.18	1.35-3.52	0.002	**

*** $p < 0.001$; ** $p < 0.01$; OR: Odds Ratio; CI: Confidence Interval. All variables adjusted for age and sex in multivariate model.

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[Figure 1] Radiological Pelvimetry Measurements - Radoievitch Angle and Ami's Line
[INSERT HIGH-RESOLUTION PELVIC RADIOGRAPH HERE] Anteroposterior pelvic radiograph demonstrating measurement techniques: (A) Radoievitch angle (α) formed between sacral long axis and horizontal reference line; (B) Ami's line (L) measured from anterior superior iliac spine to pubic tubercle; (C) Interspinous reference line (SS line) between bilateral anterior superior iliac spines. Measurement scale indicates standardized units.
[Figure 2] Comparative Pelvimetric Measurements Between Hernia Cases and Controls
[INSERT COMPARATIVE BOX PLOTS HERE] Box plots comparing: (A) Radoievitch angle (degrees) - Cases 42.8±2.3° vs Controls 40.9±2.4° ($p<0.001$); (B) Ami's line length (centimeters) - Cases 8.4±1.0 cm vs Controls 7.3±1.1 cm ($p<0.001$). Boxes show 25th-75th percentile ranges, horizontal lines indicate medians, error bars extend to ±1.96 SD. Asterisks (***) denote $p<0.001$.

DISCUSSION

In the context of inguinal hernia formation, pelvic bone anatomy plays a significant role, as highlighted in a recent study on radiological pelvimetry. This study, and it showed that three independent hernia predictors were found, all related to the position of the pelvis in relation to the inguinal canal. These predictors were, higher Radoievitch angles, or pelvic inclination, longer Ami’s lines, which indicate a longer inguinal ligament and a low-lying pubic tubercle.
As we know, hernia patients tend to have higher Radoievitch angles, suggesting that pelvic inclination affects intra-abdominal stresses within the abdominal wall, and is likely affecting the stress levels for hernia patients on their myopectineal orifice. Coming from a biomechanical perspective, a vertical pelvis can weaken the posterior inguinal wall's ability to hold its load, which results in stress to the inguinal canal as Radoievitch angle degrees vary and then fall significantly between hernia patients, 42.8 degrees and the control group, 40.9 degrees.
It’s also seen that hernia patients have greatly extended Ami’s line measures which is basically a sign of long inguinal ligaments that won't be able to properly support the posterior inguinal wall, and may even cause the whole area to be more slack and reduce the effectiveness of a system called the shutter mechanism, which is there to stop the hernia from getting worse. The internal oblique and transversus abdominis muscles flex and help out the inguinal canal by stiffening it when intra-abdominal pressure rises. But this muscle action isn’t as effective if the inguinal area is too big due to its lengthy ligaments.
Radoievitch angle and Ami’s line are virtually correlated, meaning they go hand-in-hand, and in this case, indicate a deeper understanding of the fact that a tilted pelvis and longer inguinal ligaments are two different expressions of the same kind of pelvic morphological irregularity. Well-known surrogates for this type of irregularity are low-lying pubic tubercles, found in 62% of hernia patients and 33% of control subjects. The location of the pubic tubercle has shown to be a strong indicator, and when pitted against other pelvic measurements, still stands out in a multivariate analysis, when predicting hernia development. Male hernias are more common, and the numbers are supported by significant differences in how much pelvic space the male and female pelvises can handle.
Men in the hernia group, for instance, had larger Radoievitch angles and longer Ami’s lines than their counterparts without hernias, and the gap between these two groups is very noticeable. Due to its physical makeup, the male pelvis is predisposed to hernia formation, possibly explaining why men have eight to ten times more inguinal hernias than women.
The increasing trend in pelvic readings from unilateral to bilateral, and from direct to indirect to pantaloon hernias, displays a direct correlation between anatomical adversity and clinical manifestation. A trend seen here, and backed by the idea that the people who have the worst physical attributes are most likely to suffer dual or complex pantaloon hernias. Pantaloon hernias, which consist of both a direct and an indirect hernia on one side, possess the highest pelvic readings, and therefore show us that extreme anatomical anomalies may cause multiple hernia problems.
The odds ratio calculations showed that the measured pelvic traits are powerful predictors of hernia development, and that gender was not able to completely eliminate the hazard. The implications of these discoveries strengthen hazard characterization and educated surgical decisions in preoperative assessments. Since all three pelvic measurements were found to be individually and reliably accurate in forecasting hernia chance, each gives unique data about the risk.
As indicated by these outcomes, preoperative radiological pelvimetry could be incorporated into regular surgery check-ups, and could be particularly useful in high-risk patients or those undergoing primary repair to prevent recurrence. Identifying patients who require more robust surgery, reinforcement or double-checking of the other side’s hernia, is also made possible by stratification based on pelvic readings.

CONCLUSION

Looking at the development, presentation and severity of inguinal hernias, the structure of the pelvic bone plays a significant role and can be measured by radiographic pelvimetry. The Radoievitch angle, Ami's line length and the position of the pubic tubercle are each on their own capable of predicting the onset of hernias. Radiological pelvimetry is an uncomplicated, completely painless, non-intrusive

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and very objective method of checking the anatomical risk factors, enabling us to sort out who is at risk, plan surgeries with accuracy and cut down on the likelihood of the hernia reappearing after surgery. Introducing pelvimetric analysis into routine pre-surgery check-ups may help us to pick up at-risk patients earlier, send them to a specialist more quickly, select the best surgical method for the individual anatomy, and stop the hernia from reappearing. Future studies will investigate if tweaking the surgery based on the results of the pelvimetry gives us better results for high-risk patients, and finds people who are at a high risk of hernia, so that preventive measures can be taken.

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