A Cross-Sectional Study of Adult Inguinal Hernial Orifice Diameter Estimation by Computed Tomography

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Abstract

[Purpose] This study aimed to determine an optimal method for estimating adult hernial orifice diameter using computed tomography (CT) performed with the patient in the prone position to achieve inguinal decompression of the hernia (CT hernia study).

[Methods] Fifty-four adult patients with inguinal hernia underwent laparoscopic hernia repair by transabdominal preperitoneal patch technique. Before surgical manipulation, we measured actual hernial orifice diameters in these patients. All patients underwent surgery after the CT hernia study became the standardized form of preoperative imaging for adult inguinal hernia patients in 2006 at St. Marianna University Hospital. We calculated the estimated hernial orifice diameter using four formulas for external inguinal hernias (Type I) and two formulas for internal inguinal hernias (Type II). Then, based on the preoperative images, a linear univariate regression model was created for the four type I estimation formulas by defining the estimated values as explanatory variables (X) and the actual hernial orifice diameters as objective variables (Y).

[Results] A significantly positive correlation was observed between all estimation models using preoperative diagnostic imaging and actual hernia diameter measurements in the adult patients. The most effective formulas were the estimation method mimicking 3D imaging (length of a line connecting the medial pole of the inferior epigastric artery and internal margin of the external iliac artery in the same transverse image) for type I hernias and the sagittal image method (maximum length of a line connecting the superior and inferior ends of the hernia sac [intraperitoneal tissues] projecting outside the transversalis fascia line in a sagittal image) for type II hernias.

[Conclusion] CT hernia studies that mimic 3D reconstruction in type I hernias and use sagittal images for type II hernias may be a useful method for estimating hernial orifice diameters in adult patients.

Key Words
Inguinal hernia, hernial orifice, preoperative diagnosis, computed tomography

Introduction

Inguinal hernias are common in Japan, with an estimated 150,000 surgeries performed annually. Most adult cases of internal hernia can be diagnosed with certainty by means of a detailed history and physical findings (visual examination, palpation) alone. Diagnostic imaging is usually reserved for occult hernias, which present with an absence of protrusion, despite the presence of pain and discomfort. Ultrasound and herniography are well-known diagnostic modalities1,2. However, since 2006, hospitals affili-
ated with our university have standardized the use of preoperative computed tomography (CT) performed in the prone position to achieve inguinal decompression (CT hernia study) to obtain more objective preoperative data in hernia patients. Previous studies have verified the usefulness of CT hernia studies for differentiating between internal and external inguinal hernias (diagnostic classification). However, over time, we came to believe that estimating hernial orifice diameter using two-dimensional (2D) CT imaging was challenging in inguinal hernia cases that require three-dimensional (3D) analysis. Further, it is essential to measure the hernial orifice diameter to determine preoperative diagnostic classification of hernias (also known as subtyping). The hernia subtype may determine the degree of surgical difficulty or optimal surgical technique, so estimation of the hernial orifice diameter using preoperative imaging findings is highly clinically significant.

The purpose of this study was to determine an optimal method for estimating hernial orifice diameter using CT with the patient in the prone position to achieve inguinal decompression.

Methods

Study design

We used a retrospective observational study design (analytical cross-sectional study) to allow us to study the information obtained from preoperative imaging findings and intraoperative findings and to register several eligible cases.

Patients

From 2006, 4163 adult patients aged≥18 years with inguinal hernia underwent surgery at St. Marianna University Toyoko Hospital, St. Marianna University Yokohama City Seibu Hospital, St. Marianna University School of Medicine Hospital and Kawasaki Municipal Tama Hospital. We notified all institutions participating in this study of the fact that patients who were diagnosed as having inguinal hernia and underwent treatment between May 1, 2019 and July 31, 2020 could potentially be included in the present study. The following inclusion and exclusion criteria were applied to determine which patients were registered in the study.

Inclusion criteria

1. Patients who underwent a preoperative CT hernia study.
2. Patients who underwent transabdominal preperitoneal repair (TAPP), during which the hernial orifice was measured prior to intraoperative dissection and manipulation.
3. Patients in whom the hernial orifice was measured intraoperatively.

Exclusion criteria

1. Patients diagnosed as having a femoral hernia (type III) and mixed inguinal hernia (type IV) based on preoperative imaging.
2. Patients with irreducible or incarcerated hernias.
3. Patients with a history of lower abdominal surgery, including hernia repair.
4. Patients who refused to be enrolled in this clinical trial.

Ultimately, 54 patients who met the above conditions were included in the present study. This study was approved by the institutional review board at St. Marianna University School of Medicine (Approval No.: 1065).

Terms and definitions used in this clinical trial

Actual hernial orifice diameter: The Japanese Hernia Society describes the measurement of the hernial orifice as follows: “Measurement takes place at the level of the transversalis fascia posterior to the preperitoneal stratum disjunctum. As a rule, the maximum diameter is measured during laparoscopic surgery”\(^4\). To standardize the measurement conditions during this study, we defined the actual hernial orifice diameter as the geometric mean of the transverse and longitudinal diameters measured prior to intraoperative dissection and manipulation.

Medial pole of the inferior epigastric artery: Anatomically, the inferior epigastric artery branches off from the external iliac artery and then follows a course along the superior aspect of the medial margin of the lateral inguinal fossa, entering the dorsolateral margin of the rectus abdominis muscle. In the event of an external inguinal hernia, the inferior epigastric artery is displaced and deviated towards the midline as a result of enlargement of the internal inguinal ring (Figs. 1, 2). The most medial point of the curve followed by the inferior epigastric artery within the myopectineal orifice\(^5\) depicted on coronal images was defined as the medial pole of the inferior epigastric artery.

Imaging conditions for the CT hernia study

A 64-row CT scanner was used for imaging
(Aquilion™ 64, Canon Medical Systems Corporation, Tokyo). The imaging conditions were as follows: tube voltage, 120 kVp; tube current, CT-auto exposure control; beam pitch, 0.828; slice thickness, 5 mm; and reconstruction function, FC04. Patients were placed in the prone position, and a bath towel rolled up to a thickness of approximately 20 cm was placed anterior to the abdomen and femoral region, which resulted in decompression of the inguinal region. A plain abdominal CT scan was then performed to create transverse and coronal images.

Preoperative diagnostic hernia classification and hernial orifice diameter estimation methods used in the CT hernia studies

Preoperative diagnostic hernia classification

If the hernia sac and contents prolapsed lateral to the inferior epigastric artery and superior to the inguinal ligament, this was defined as an external inguinal hernia (type I), and if they prolapsed medial to the artery, this was defined as an internal inguinal hernia (type II).

Hernial orifice diameter estimation methods

We estimated the hernial orifice diameters using the four formulas for type I and two formulas for type II hernias shown below, which were defined based on the measurement methods currently being implemented at St. Marianna University Hospital.

1-① The length of a horizontal line connecting the medial pole of the inferior epigastric artery to the external margin of the peritoneum on a coronal image slice depicting the medial pole of the inferior epigastric artery is measured (Fig. 2).

1-② A The maximum transverse diameter of the hernia sac (intraperitoneal tissues) projecting outside of the transversalis fascia in approximately three transverse image slices depicting the point at which the inferior epigastric artery flows into the lateral margin of the rectus abdominis muscle is measured (Fig. 3).
I-③ The length of a line connecting the point at which the inferior epigastric artery bifurcates from the external iliac artery and the prolapsed hernia sac (intraperitoneal tissues) in the same transverse image is measured (Fig. 4).

I-④ The length of a line connecting the medial pole of the inferior epigastric artery and the internal margin of the external iliac artery in the same transverse image is measured (Fig. 5).

Figure 2. Estimation method ① for type I hernia (Right side)

Figure 3. Estimation method ② for type I hernia (Right side, a same case as Figure 2)
Hernial orifice diameter estimation methods for type II hernias

II-① The maximum length of the line connecting the medial and lateral ends of the hernia sac (intraperitoneal tissues) projecting outside of the transversalis fascia line in a transverse image is measured (Fig. 6).

II-② The maximum length of the line connecting the superior and inferior ends of the hernia sac (intraperitoneal tissues) projecting outside of the transversalis fascia line in a sagittal image is measured (Fig. 7).

To prevent accidental measurement errors, each of the above-mentioned measurements was performed by three surgical specialists with over 10 years of experience in treating adult inguinal hernia patients, and the mean value of these three measurements was used as the estimated hernial orifice diameter.

Conditions for laparoscopic inguinal hernia repair

The standardized surgical conditions at all four institutions participating in this study were surgery performed under general anesthesia with the patient in a supine position and an insufflation pressure of 10 cmH₂O.

Method of measuring actual hernial orifice diameter

First, a 4–5 cm length of 4–0 nylon suture was measured and cut outside of the body for use as a ruler. The ruler was guided into the herniated region within the peritoneal cavity, then matched to the transverse and longitudinal diameters of the prolapsed peritoneal site prior to peritoneal dissection and manipulation, and finally, withdrawn from the body and measured using markings (1 mm standard) (Fig. 8). If the intraperitoneal contents had prolapsed into the hernial sac, the hernial orifice was measured only after these contents were reduced into the peritoneal cavity.
Statistical analysis

To ensure the lack of gender bias in the background of the patients targeted in this study, we first performed a chi-square test between the results of the Kanagawa Hernia Association questionnaire survey and those of our 4 hospitals. The estimated and actual hernial orifice diameters obtained during the CT hernia studies were analyzed as explanatory and objective variables, respectively, during univariate regression analysis. We created linear univariate regression models for the four type I formulas and the two type II formulas and then compared the goodness of fit using a coefficient of determination ($R^2$) to determine the optimal estimation method. We limited the patients to those with relatively large actual hernial orifice diameters of ≥25 mm, created a linear univariate regression model for estimation methods I-① to I-④ for type I hernias. A p value of <0.05 was considered to be statistically significant. JMP-14 (SAS Institute Inc., Cary, NC, USA) was used to perform the statistical analysis.

Results

In total, 54 patients were eligible for this study. The breakdown of these patients is shown in Table 1. There were no significant differences in terms of the incidence or sex ratios of the patients with external and internal inguinal hernias. When we compared the results for type I and II inguinal hernias to those obtained by the Kanagawa Hernia Association questionnaire survey (KHAS), we also found no significant differences. (Table 1)

Analysis results for type I hernias

The estimated and actual hernial orifice diameters obtained during the CT hernia studies using estimation methods I-① to I-④ for type I hernias were analyzed as explanatory and objective variables, re-
spectively, during univariate regression analysis. We then created a linear univariate regression model (Fig. 9). The regression formulas obtained are listed below.

Estimation method ①: Y=12.0+0.52X (slope 0.52, p=0.0019, R²=0.24)
Estimation method ②: Y=5.63+0.74X (slope 0.74, p<0.001, R²=0.40)
Estimation method ③: Y=12.8+0.53X (slope 0.53, p=0.016, R²=0.15)
Estimation method ④: Y=4.7+0.79X (slope 0.79,
Table 1. Breakdown of Hernia Cases

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<td>Report Totals for</td>
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<td>1615</td>
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<td>2016/2017(^{(1)}) (KHAS)</td>
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Gender (External inguinal hernia)

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<tr>
<td>KHAS</td>
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<td>586</td>
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Gender (Internal inguinal hernia)

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<td>KHAS</td>
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Figure 9. Linear single regression models for the four type I formulas
The regression lines slopes for all four estimation methods were positive, indicating a significant correlation. Furthermore, based on the goodness of fit obtained from the linear regression model, we determined that estimation methods I-2 and I-4 were the most powerful for type I hernias.

As a supplementary analysis, for actual hernial orifice diameters of ≥25 mm, we created a linear univariate regression model for estimation methods I-1 to I-4 for type I hernias, and compared the results (Fig. 10). The regression formulas obtained are listed below.

Estimation method 1 (≥25 mm): Y=22.05+0.34X (slope 0.34, p=0.028, R²=0.25)
Estimation method 2 (≥25 mm): Y=17.96+0.46X (slope 0.46, p=0.015, R²=0.30)
Estimation method 3 (≥25 mm): Y=31.08+0.03X (slope 0.03, p=0.909, R²=0.0008)
Estimation method 4 (≥25 mm): Y=14.47+0.56X (slope 0.56, p=0.0029, R²=0.41)

(Y: actual hernial orifice diameter [mm], X: estimated hernial orifice diameter [mm])

Based on the above, estimation methods I-1, I-2 and I-4 for type I hernias showed a significantly positive correlation with actual hernial orifice diameters ≥25 mm. On the basis of the goodness of fit obtained from the linear regression model, we determined that estimation method I-4 was most powerful for type I.

Analysis results for type II hernias

The estimated and actual hernial orifice diameters obtained during the CT hernia studies using estimation methods II-1 and II-2 for type II hernias were analyzed as explanatory and objective variables, respectively, during univariate regression analysis. We then created a linear univariate regression model (Fig. 11). The regression formulas obtained are listed below.

Estimation method 1: Y=0.53+0.87X (slope 0.87, p=0.006, R²=0.43)
Estimation method 2: Y=-5.9+1.05X (slope 1.04, p=0.003, R²=0.47)

(Y: actual hernial orifice diameter [mm], X: estimated hernial orifice diameter [mm])

Figure 10. Linear single regression models for the four type I formulas in large actual hernial orifice diameters of ≥25 mm
A significant correlation was observed for both estimation methods. On the basis of the goodness of fit obtained from the linear regression model, we determined that estimation method II-(2) was more powerful for type II hernias.

Discussion

According to the inguinal hernia treatment guidelines of the Japanese Hernia Society, “It is possible to diagnose 70 to 90% of all inguinal hernias using physical findings alone, and diagnostic imaging, such as CT, MRI, or herniography, should only be used for diagnosis in certain specific cases (cases with indistinct physical findings, hernias at non-classical sites, or indistinct hernias)”⁴. However, the guidelines also state that “the inguinal hernia classification may be significant for assessing severity and assisting selection of the surgical technique”. Although this is acceptable when performing preoperative diagnosis using physical findings alone, it is obvious that diagnostic imaging is essential for objective preoperative diagnostic classification. Despite this, we expect the use of this type of imaging to be significant, which means there are certain contradictions in these statements. First, the importance of accurate preoperative classification after establishing a comprehensive treatment strategy for cases of inguinal hernia has already been reported⁷. Reports have also indicated that the selection of an optimal mesh size when predicting the preoperative degree of surgical difficulty and planning the method of inguinal incision during TAPP contribute to improved therapeutic outcomes⁸,⁹. In addition, the majority of patients with hernial orifices ≥3 cm suffer from sliding inguinal hernias, which significantly prolongs the duration of surgery¹⁰. Hayakawa¹¹ reported that it is usually difficult to perform laparoscopic repair of type I hernias originating from the vaginal process of the peritoneum (de novo, sliding type I hernias). Based on the above, diagnostic hernia classification (subtyping) by means of preoperative diagnostic imaging would appear to be important.

The most well-known preoperative diagnostic classification was proposed by Nyhus et al., although within Japan, we generally use the inguinal hernia classification provided by the Japanese Hernia Society, which is a simplified and easier to understand modification of the former. However, this classification is based on intraoperative findings, and there are no standardized diagnostic modalities for preoperative imaging findings. Reports to date have documented hernia classification methods based on preoperative diagnostic imaging to differentiate between type I and type II hernias⁴,¹³ but there have been no widely read reports discussing hernial orifice measurement. For this reason, we attempted to determine a more accurate preoperative hernial orifice diameter estimation method during this study to establish a hernia classification system based on preoperative diagnostic imaging.

Type I hernias arise in an area known as the lat-
eral triangle, which is surrounded by the linea semilunaris, the inguinal ligament and inferior epigastric artery. The hernial orifice is widely understood to include the internal inguinal ring. It is therefore challenging to approximate the type I hernial orifice using 2D imaging. The ideal method for estimating hernial orifice diameter would be to first approximate the hernial orifice size as closely as possible by creating a 3D hernia model using reconstructed 3D CT images and then actually measuring the orifice diameter. However, the creation of reconstructed 3D CT images is somewhat expensive and requires specialized software that, moreover, must be operated by an experienced practitioner, meaning that this method cannot be put to general use. Therefore, we used estimation methods based on 2D CT imaging findings in this study.

All four of the estimation methods for type I hernias showed positive correlations with the hernial orifice diameter, although the goodness of fit for methods I-① and I-③ was less than that for methods I-② and I-④. The reason for the poor goodness of fit for estimation method I-① for type I hernias is that the measurement was defined as the length of a horizontal line connecting the medial pole of the inferior epigastric artery to the external margin of the peritoneum. The lateral margin of type I hernias is smooth because the parietal peritoneum migrates into the hernial sac, so it is difficult to accurately determine the lateral margin of the peritoneum on the images, and we predict that there can be a significant difference between the estimated and actual values. The hernial orifice diameter was measured before peritoneal detachment and was expected to be smaller than the post-detachment diameter, which was used for actual hernia classification. Considering the peritoneal and preperitoneal manipulations, we set this to ≥25 mm. Although a significant positive correlation with estimation method I-③ for type I hernias was observed in all eligible patients, no significant correlation was observed when we limited the patients to those with actual hernial orifice diameters ≥25 mm. We believe the reason for this is that the measurement point on the images, which is the medial margin of the hernial orifice, is presumed to be the point at which the inferior epigastric artery bifurcates from the external iliac artery, and the lateral margin of the hernia sac in the same imaging slice is considered to be the lateral margin of the hernial orifice. Neither of these points correspond to the actual medial and lateral hernial orifice margins, so the estimates will always be smaller than the actual size.

Meanwhile, estimation methods I-② and I-④ for type I hernias may be powerful models for estimating hernial orifice diameter. The rationale for setting estimation method I-② for type I hernias was the fact that direct measurement is possible as it is difficult to locate the hernial orifice on 2D images, and it is most likely that the hernial orifice diameter immediately after hernial sac prolapse most closely approximates the actual hernial diameter. This was shown to be the most powerful estimation method in all eligible cases, although when we limited the study to patients with large hernial orifice diameters, a high proportion of these patients had large hernia sacs observed during imaging obtained immediately after prolapse through the hernial orifice. This inevitably led to overestimation of the measurement values, and the results were inferior to those obtained with estimation method I-④.

Estimation method I-④ for type I hernias achieved the best goodness of fit obtained from the linear regression models, likely because this method uses a mimicked 3D estimation method to perform measurements in a horizontal direction to offset the gap arising in the direction of the body access when performing diagnosis of the external semicircle of the medial luminal surface of the hernial orifice, which is where the inferior epigastric artery has been compressed and deviated medially due to the type I hernia.

Type II hernias prolapse through the area known as the lateral triangle, as described above, and are also known as direct inguinal hernias because the protrusion occurs more laterally due to weakness of the transversalis fascia. We found better goodness of fit for the models when imaging was performed in a sagittal rather than in a transverse plane. We believe that the type II hernias are similar to abdominal wall hernias as they prolapse as a result of weakness of the abdominal wall. This supports the utility of performing diagnostic imaging in a sagittal plane during routine clinical practice. However, Spiegel hernias may occur as a complication of type II hernias, so caution is advised during diagnosis. Burkhardt et al. reported that the crescent sign, formed laterally as a result of compression of the hernia contents (such as the testicular vessels and spermatic cord) in the inguinal canal in a transverse plane in cases of type II hernia, is useful for diagnosis. They also reported that diagnosis should be performed in this plane and that imaging in the sagittal plane should only be used for orifice diameter measurement.
There are several limitations in the present study, including the facts that the estimation models were inaccurate for cases with small hernial orifice diameters and were imperfect. As a rule, the imaging slices used in this study for the estimation models determined to be the most optimal (method I-④ for type I and II-② for type II hernias) were 4.7 and -5.9 mm, respectively. As a result, there was a gap between these locations and the origin, which meant that the inaccuracy of the estimated value increased as the size of the explanatory variable decreased. These estimation models can be considered to be permissible when the $R^2$ values are 0.5 for estimation method I-④ for type I hernias and 0.47 for estimation method II-② for type II hernias. However, these estimation methods cannot be said to be perfect and need to be further optimized in a larger patient population in the future.

**Conclusion**

Two-dimensional CT hernia studies that mimic 3D reconstruction in type I hernias and that use sagittal images for type II hernias may be useful for estimating hernial orifice diameters in adult patients.

**Conflicts of Interest**

The authors have nothing to disclose.

**References**