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Research article

# Defect width as a percentage of transverse abdominal diameter: An index to predict the requirement for component separation in incisional hernia repair☆

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ABSTRACT

*Purpose:* Preoperative decision making prior to incisional hernia repair brings benefits but also presents challenges. Defect width (DW) is the key index in hernia staging but does not precisely indicate the requirement for component separation (CS). DW as a percentage of transverse abdominal diameter (TAD) determined by CT imaging was investigated for its capacity to indicate the necessity of CS for successful defect closure under physiological tension.
*Methods:* A total of 116 patients treated for incisional hernia by surgery between April 1st, 2015 and September 30th, 2020 were enrolled and clinical data retrospectively analyzed. All hernias were repaired with defect closure and mesh reinforcement. 82 patients received Rives-Stoppa repair (RS group) and 34 Rives-Stoppa repair with CS (CS group). Preoperative CT images were reviewed to measure maximum DW and TAD at umbilical level and the DW/TAD percentage (DTP) calculated. Accuracies of DW and DTP in predicting necessity of CS were compared through statistical analysis.
*Results:* Mean RS DW was 59.41 ± 18.70 mm and CS DW 105.76 ± 13.47 mm ($p = 0.000$). Mean RS DW/TAD percentage was 21.25 ± 6.48 and CS DW/TAD 38.56 ± 6.26 ($p < 0.05$). Area under the curve (AUC) for receiver operating characteristic (ROC) curves gave values of 0.798 for DW and 0.825 for DTP ($p < 0.05$).
*Conclusion:* DTP is a reliable index with greater accuracy than DW for prediction of the necessity of CS in incisional hernia repair.

*Abbreviations:* DW, Defect width; CS, Component separation; RS, Rives-Stoppa; TAD, Transverse abdominal diameter; DTP, DW/TAD percentage; AUC, Area under the curve; ROC, Receiver operating characteristic; TAR, Transversus abdominis release; EHS, European Hernia Society; ASA, American Society of Anesthetists; BMI, Body mass index; PPP, Progressive pneumoperitoneum; CCS, Chemical component separation; IPOM, Intraperitoneal onlay mesh.

☆ Ping Wang conceived and designed the study. Zicheng Guo collected, analyzed and interpreted the data. Zicheng Guo wrote the manuscript as well, so he contributed equally as Ping Wang. Hua Jin, Zhun Chen, and Qingqing Li collected data and provided critical revisions that are important for the intellectual content. Yonggang Huang approved the final version of the manuscript, and obtained funding.

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## 1. Introduction

Abdominal wall incisional hernia is a common complication following abdominal surgery with an incidence of 9–22 % after laparotomy [1,2]. It is often impossible to close the fascia during surgery for large and complex incisional hernias and component separation (CS) or external oblique muscle flap techniques are required for abdominal wall reconstruction [3–5]. CS by transversus abdominis release (TAR) is often used for giant incisional hernia with Rives-Stoppa repair (open sublay repair) for closure [6–8]. However, inadequate preoperative preparation may result in poor repair outcomes, especially for surgeons inexperienced in CS techniques. This observation reveals the need for accurate preoperative assessment to decide the necessity for concurrent CS. Abdominal wall defect width (DW) is the key component of hernia staging by European Hernia Society (EHS) [9] criteria but does not reliably predict appropriate surgical approaches [5]. However, we have hypothesized that the DW measured by preoperative computed tomography (CT) as a percentage of the transverse abdominal diameter (TAD) at the umbilical level (DW/TAD percentage or DTP) gives a better evaluation of the patient's abdominal wall muscle morphology and compliance (Fig. 1). TAD at the umbilical level reflects the volume of intra-abdominal fat and excess fat may increase intra-abdominal pressure and weaken the myofascial layer of the abdominal wall, affecting defect closure [10–13].

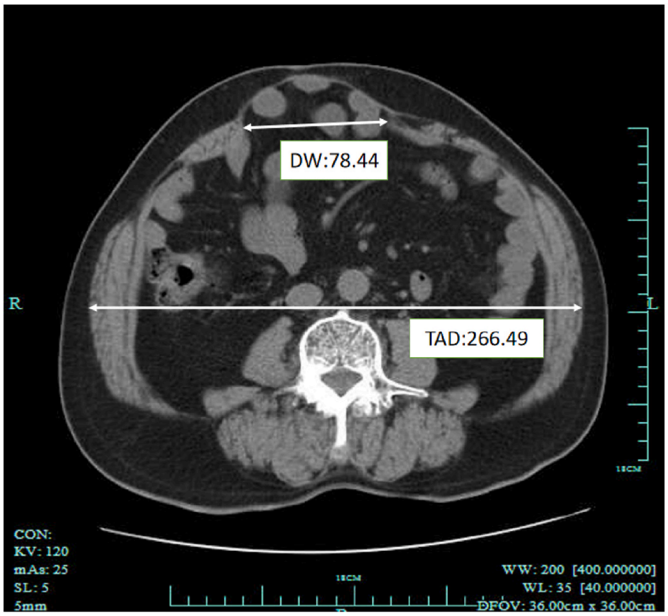
## 2. Methods

### *2.1. Subjects*

A total of 116 patients, 35 males and 81 females, of mean age 65 ± 13.18 (range: 31–89), who underwent open sublay mesh repair of abdominal wall incisional hernia between April 01, 2015 and September 30, 2020 were enrolled. All patients had had a CT scan within the year prior to surgery. Ethical approval was granted by the hospital medical ethics committee and patients gave informed consent prior to surgery for the collation and publication of clinical data.

### *2.2. Inclusion criteria*

(1) A history of previous abdominal surgery involving abdominal wall incisional hernia located in the midline region classified according to the criteria of the European Hernia Society, incisional hernia classification M1-M5 and W1-W3(The range of the defect width is from 26.97 mm to 140.52 mm) [14]; (2) Surgical approach using Rives-Stoppa mesh repair with or without TAR; (3) Complete medical history including preoperative abdominal CT examination, previous surgeries and intraoperative surgical records.




DW: defect width and TAD: transverse abdominal diameter. All units are mm. DTP was 29.43% for this representative example.

**Fig. 1.** Representative preoperative CT scan.
DW: defect width and TAD: transverse abdominal diameter. All units are mm. DTP was 29.43 % for this representative example.

### 2.3. Exclusion criteria

(1) Presence of infection or micro abscess in the abdominal wall; (2) Abdominal wall incisional hernia with incarceration and strangulation; (3) Presence of chronic complications, such as intestinal obstruction, intestinal fistula and severe abdominal pain; (4) Severe diseases of the heart, lung, liver, kidney, brain or other organs that has contraindications for anesthesia and surgery; (5) Inability to cooperate with follow-up or incomplete perioperative or postoperative examinations.

### 2.4. Surgical methods

(1) Rives-Stoppa sublay repair (RS group): An incision was made in the skin and the abdominal wall defect explored to locate the edges. The hernia was freed on both sides along the posterior sheath of the rectus abdominis muscle and between the rectus abdominis muscle to completely free the posterior space. The posterior sheath and peritoneum were closed and the mesh placed in the retromuscular space [15].

(1) Rives-Stoppa sublay repair + component separation (CS group): Rives-Stoppa sublay repair was performed as above and component separation achieved using TAR, as previously described by Novitsky [16].

### 2.5. Perioperative management

Preoperative CT of the chest and abdomen, routine blood, liver and kidney function and other routine tests were performed prior to surgery and routine prophylactic antibiotics (cephalosporins) administered half an hour before surgery. Patients were advised to wear a post-surgical bellyband for 6 months or more to ensure gradual recovery of abdominal wall function.

### 2.6. Observation indicators and statistical methods

Demographic and clinical data, including height, weight, body mass index (BMI), operating time, bleeding volume and operation method were recorded. DW/TAD percentage was calculated according to the formula: DW/TADx100. GraphPad Prism 8.0 software (GraphPad Software Inc., San Diego, CA, USA) or SPSS 24.0 software (SPSS Inc., Chicago, IL, USA) were used for data analysis. Independent samples of measurement data were compared by *t*-test and count data by $\chi^2$ test. A value of $p < 0.05$ was considered to indicate statistical significance. MedCalc 20.0 software was used to draw ROC curves and calculate the area under the curve.

## 3. Results

### 3.1. General patient data

No significant difference in gender composition ($p = 0.742$), ASA score 1–2 (low risk of anesthesia) and ASA score 3–4 (high risk of anesthesia) ($p = 0.378$) or EHS classification M1-M2 and M3-M5 ($p = 0.754$) was present between RS and CS groups. Mean ages were $64.68 \pm 14.13$ years for RS and $66.65 \pm 10.86$ for CS ($p = 0.469 > 0.05$) and BMIs were $24.87 \pm 3.51$ for RS and $25.11 \pm 4.15$ for CS groups ($p = 0.746$), showing no significant differences. Mean DW was significantly lower at $59.41 \pm 18.70$ mm for RS compared with $105.76 \pm 13.47$ mm for CS ($p = 0.000 < 0.05$). DTP at the umbilical level was also significantly lower at $21.25 \pm 6.48$ for RS compared with $38.56 \pm 6.26$ for CS ($p = 0.000$). General patient data is presented in Table 1.

**Table 1**
Basic patient information.

| | RS group | CS group | *p* |
|---|---|---|---|
| N | 82 | 34 | |
| Gender | | | 0.742[a] |
| Male | 24 | 11 | |
| Female | 58 | 23 | |
| Age (years) | 64.68 ± 14.13 | 66.65 ± 10.86 | 0.469 |
| BMI (kg/m$^2$) | 24.87 ± 3.51 | 25.11 ± 4.15 | 0.746 |
| DW(mm) | 59.41 ± 18.70 | 105.76 ± 13.47 | 0.000 |
| TAD(mm) | 280.14 ± 16.76 | 273.06 ± 20.75 | 0.084 |
| DTP(DW/TADx100) | 21.25 ± 6.48 | 38.56 ± 6.26 | 0.000 |
| Operation time(min) | 137.29 ± 26.79 | 141.17 ± 19.69 | 0.390 |
| Intraoperative bleeding(ml) | 71.24 ± 26.92 | 72.85 ± 27.95 | 0.773 |
| ASA score | | | 0.378[a] |
| 1-2 | 56 | 26 | |
| 3-4 | 26 | 8 | |
| EHS classification[b] | | | 0.754[a] |
| M1-M2 | 14 | 5 | |
| M3-M5 | 68 | 29 | |

[a] Count data compared by $\chi^2$ test.
[b] EHS classification: European Hernia Society classification of incisional hernia.

3.2 ROC curves were plotted for DW and DTP and area under the curve (AUC) calculated. DTP (AUC = 0.825) was more accurate than DW (AUC = 0.798) in predicting the need for fascial release ($p = 0.0196$, Fig. 2).

3.3 Scatter plots were used to label DW and DTP in the same coordinate system and means calculated for each group of patients. DW was found to predict fascial release requirement at a significance level of $p < 0.01$ and DTP predicted fascial release requirement at $p < 0.001$ (Fig. 3). Concomitant TAR was required in 72.73 % of patients when the DTP was >40 (Table 2).

## 4. Discussion

The aim of incisional hernia repair is to restore abdominal wall integrity and normalize function and appearance. CS, progressive pneumoperitoneum (PPP), external oblique muscle flap technique and chemical component separation (CCS) have been proposed as approaches to achieving functional reconstruction [5,17,18]. Rives-Stoppa retromuscular repair was first proposed by Stoppa and improved by Rives J and Wantz GE and has become the standard method for repairing complex abdominal wall hernias [19–21]. Surgical methods are categorized as Onlay, Sublay and IPOM depending on which plane the mesh is placed in for incisional hernia repair. In the Rives-Stoppa procedure, the mesh is placed in the sublay plane. Open sublay repair by retro-rectus mesh involves a higher collagen type 1/collagen type 3 ratio than the anterior muscle or Onlay level and results in a higher postoperative tensile strength of the incision, improving postoperative recovery of abdominal wall function [22]. In cases of large abdominal wall defects or poor abdominal compliance, sublay repair alone is not sufficient to close the abdominal wall defect and further myofascial release is required [23]. TAR is compatible with Rives-Stoppa repair and produces more extensive lateral freeing and greater midline advancement of the posterior rectus abdominis sheath and myofascia. Thus, a wider posterior myofascial plane is presented for placement of a larger mesh [16,24].

The size of the abdominal wall defect may give an initial indication of the need for myofascial release but does not take into account patient status, abdominal fat accumulation and abdominal wall compliance [25]. Chinese patients are generally smaller than Caucasians and an equivalent defect width account for a higher proportion of the total abdominal wall transverse width with implications for the ease of surgical closure. A CS approach may facilitate defect closure but pre-operative predictions of the necessity for CS have not previously been straightforward [26]. Calculation of the abdominal wall defect width as a percentage of the transverse abdominal diameter at the umbilical level to produce the DTP percentage value allows more accurate assessment of the ease of incisional hernia closure and the need for myofascial release. The current retrospective analysis found that DW and DTP give an indirect assessment of the need for myofascial release. AUC values for the ROC curves produced higher values for DTP than DW, showing greater confidence in the former for evaluation of myofascial release needs before surgery. The DTP value has utility to inform surgical decisions prior to the operation.

CT results have previously been used to stratify patients according to defect diameter and the ratio to abdominal wall circumference. Franklin found that preoperative determination of the defect diameter: abdominal wall ratio or defect area gave indications of the necessity for tissue structure separation [27]. Christy used a tissue separation index for preoperative prediction of the difficulty of fascial closure during ventral open hernia repair but the anatomical requirements may be a limiting factor [28]. Preoperative CT measurements of hernia defect and abdominal wall thickness have been used to predict wound complications and the need for complex abdominal wall reconstruction [29]. Du et al. believe that quantitative CT measurements have significant value in predicting component separation preoperatively, and the CT attenuation of the abdominal wall muscles can serve as an independent predictive factor for component separation surgery [30].The use in the current study of scatter plots to label DW and DTP in the same coordinate system has revealed the greater accuracy of DTP over DW in predicting the need for fascial release.

Myofascial release is required when Rives-Stoppa retroperitoneal repair is inadequate to achieve fascial closure. The unfamiliarity

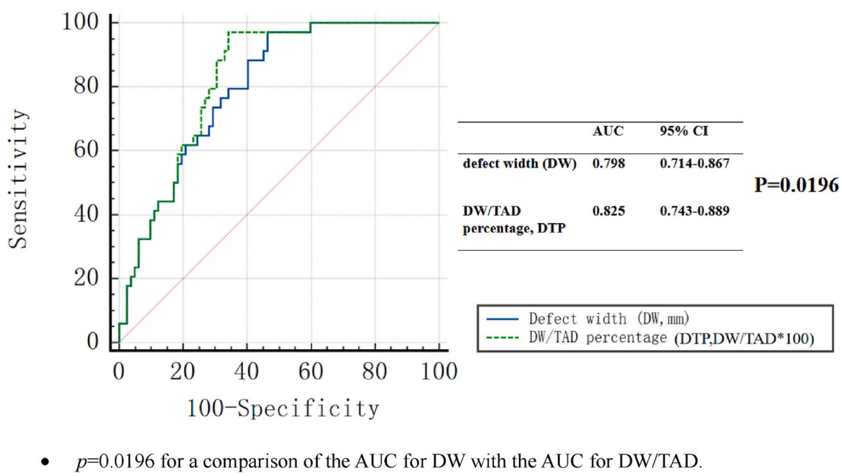



**Fig. 2.** ROC curves for DW and DTP.
• $p = 0.0196$ for a comparison of the AUC for DW with the AUC for DW/TAD.

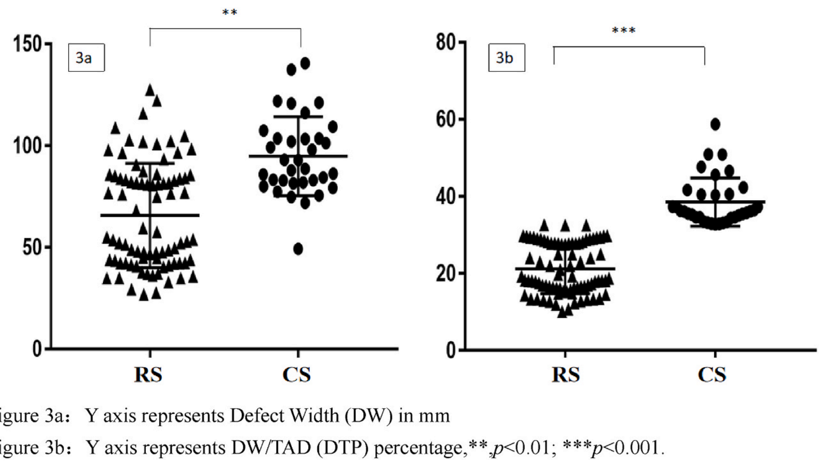



**Fig. 3.** Scatter plot for DW and DTP.
Fig. 3a:Y axis represents Defect Width (DW) in mm.
Fig. 3b:Y axis represents DW/TAD (DTP) percentage,**,$p < 0.01$; ***$p < 0.001$.

**Table 2**
Prediction of need for CS by DTP value.

| | DTP<20 n (%) | DTP 20–29.9 n (%) | DTP 30–39.9 n (%) | DTP≥40 n (%) |
|---|---|---|---|---|
| N | 44 | 35 | 25 | 11 |
| Need for CS (ratio) | 1(2.27) | 11(31.43) | 14(56.00) | 8(72.73) |

of the surgeon with the procedure may result in poor healing or additional complications, including abdominal wall nerve injury, muscle atrophy, skin necrosis or abdominal wall hernia recurrence [31]. Such complications highlight the need for strategies to facilitate an appropriate level of pre-operative planning. Novitsky has recommended the use of TAR for abdominal wall defects ≥9 cm [32]. However, successful defect closure is also influenced by intra-abdominal fat distribution and differences in abdominal wall compliance. In cases of poor abdominal wall compliance, TAR may be required to close defects of only 6 cm. Thus the absolute value of defect width cannot be used as the sole criterion. The current paper introduces abdominal wall defect width (DW) as a percentage of the transverse abdominal diameter (TAD) at the umbilical level (DTP) as an index to gauge the likelihood of TAR being necessary. Factors affecting abdominal wall closure were taken into account. DTP may be used to inform patients of the risks involved and to guide preoperative surgical planning.

There is currently no consensus on definitive criteria for the necessity of component separation. The compliance of the abdominal wall and the ability to close the defect are influenced by the patient's obesity, body habitus and other factors and defect width alone cannot accommodate these variables. The DTP guides surgical planning using percentages to exclude the effects of other variables on operative strategy.

## 5. Conclusion

A new evaluation index is introduced for the indirect assessment of the degree of intra-abdominal fat accumulation and thus to predict the ease of abdominal wall defect closure. The index consists of abdominal wall defect width (DW) as a percentage of the transverse abdominal diameter (TAD) at the umbilical level (DTP) and is suggested as a guide for clinicians in determining the need for myofascial release.

## CRediT authorship contribution statement

**Ping Wang:** Supervision, Conceptualization. **Zicheng Guo:** Writing – original draft, Resources, Data curation. **Hua Jin:** Methodology, Formal analysis. **Zhun Chen:** Methodology, Data curation. **Qingqing Li:** Writing – review & editing, Resources. **Yonggang Huang:** Writing – review & editing, Funding acquisition.

## Compliance with ethical standards statement

This study was approved by Institutional Review Board approval and the study including human participants had been performed in accordance with the ethical standards of the Declaration of Helsinki and its later amendments.

## Data availability statement

Data associated with this study has been deposited into an institutional available repository, and it will be made available publicly on request.

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## Declaration of competing interest

Ping Wang, Zicheng Guo, Hua Jin, Zhun Chen, Qingqing Li, Yonggang Huang declare that they have no conflict of interest. All the authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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