

Computed Tomography Image Analysis in Abdominal Wall Reconstruction: A Systematic Review

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Background: Ventral hernias are a complex and costly burden to the health care system. Although preoperative radiologic imaging is commonly performed, the plethora of anatomic features present and available in routine imaging are seldomly quantified and integrated into patient selection, preoperative risk stratification, and perioperative planning. We herein aimed to critically examine the current state of computed tomography feature application in predicting surgical outcomes.

Methods: A systematic review was conducted in accordance with the Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA) checklist. PubMed, MEDLINE, and Embase databases were reviewed under search syntax “computed tomography imaging” and “abdominal hernia” for papers published between 2000 and 2020.

Results: Of the initial 1922 studies, 12 papers met inclusion and exclusion criteria. The most frequently used radiologic features were hernia volume ($n = 9$), subcutaneous fat volume ($n = 5$), and defect size ($n = 8$). Outcomes included both complications and need for surgical intervention. Median area under the curve (AUC) and odds ratio were 0.68 (± 0.16) and 1.12 (± 0.39), respectively. The best predictive feature was hernia neck ratio > 2.5 (AUC 0.903).

Conclusions: Computed tomography feature selection offers hernia surgeons an opportunity to identify, quantify, and integrate routinely available morphologic tissue features into preoperative decision-making. Despite being in its early stages, future surgeons and researchers will soon be able to integrate 3D volumetric analysis and complex machine learning and neural network models to improve patient care. (*Plast Reconstr Surg Glob Open* 2020;8:e3307; doi: [10.1097/GOX.0000000000003307](https://doi.org/10.1097/GOX.0000000000003307); Published online 16 December 2020.)

INTRODUCTION

Ventral hernias persist as a common and extremely costly problem to treat and manage. The most recent estimates approximate that at least 348,000 ventral hernia repairs occur annually.¹ Incidence of ventral hernia repair results largely from incisional hernias (IHs) following abdominal surgery. Depending on the type of abdominal surgery, IH incidence is reported to be between 3.8% and 15%.^{2,3} Moreover, patients with IH report significant impacts on their quality of life, affecting a wide range of domains to include body image, mood, and physical ability.^{4,5}

Current risk factor analysis of postoperative complications is limited and focus on patient history and comorbidity.⁶ As standard of care, surgeons rely on physical examination and radiologic imaging; however computed tomography (CT) features are not extensively studied to predict surgical outcomes.^{7,8} Despite their lack of incorporation into surgical practices, CT scans are readily ordered as part of the routine work up of preoperative planning. A host of morphologic CT features can be extracted into quantitative metrics able to guide hernia repair through the stages of perioperative care.

Various studies have evaluated the incorporation of imaging into preoperative planning. For example, studies have estimated hernia sac volume size and abdominal cavity size using preoperative imaging to guide surgical techniques in reconstructing the abdominal wall.⁹ Additionally, these calculations have been used to predict the ability to achieve tension-free fascial closure, allowing surgeons

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to either preoperatively plan or refer patients to a more specialized surgeon.¹⁰ Presurgical planning that incorporates information from imaging simultaneously aids the surgeon in identifying the optimal repair technique and informs patient counseling.¹¹ To further bolster these efforts to utilize preoperative imaging to improve surgical planning and patient care, our study aimed to systematically review the literature on publications evaluating the use preoperative CT features associated with perioperative ventral hernia outcomes. We theorize that the utilization of morphologic CT features will improve patient selection, perioperative decision-making, and postoperative complications.

METHODS

Search Strategy

A full literature review (systematic review) was conducted using the databases PubMed, MEDLINE, Web of Science, and Embase. A search syntax strategy was devised using keywords pertaining to “computed tomography imaging” and “abdominal hernia.” Specifically, Boolean operators AND/OR were used to combine the following search terms: “abdominal hernia,” “hernia repair,” “incisional hernia,” “ventral hernia,” “ventral hernia repair,” “complex hernia repair,” “abdominal wall reconstruction,” “computed tomography,” “preoperative imaging,” “morphologic features,” “pre-operative characteristics,” “preoperative computed tomography,” “CT scan features,” “Computed tomography imaging,” “preoperative,” and “surgical outcomes.” This systematic review was conducted in accordance with the Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA) checklist.¹²

Eligibility Criteria

Inclusion criteria encompassed articles describing the use of CT radiographic features to assess surgical outcomes in ventral hernia repair, including pre-, intra-, and postoperative outcomes. Both prospective and retrospective study designs, including case-series and cohort studies, were included. Articles were considered if they were published in the year 2000 or after and were available in English or had an English translation.

Articles were excluded if they were not available in English or did not have an English translation. Review articles, editorials, and abstracts were excluded. Additionally, articles that did not utilize radiologic features in the setting of a ventral hernia repair or did not discuss the evaluation of a surgical outcome were excluded. Two authors (OE, SO) independently reviewed all search results at the title and abstract level for inclusion and exclusion criteria. Discrepancies between author article reviews were resolved through discussion or consultation with a third, experienced author (JPF).

Data Extraction and Outcome

Data extracted from each study included: (1) authors, (2) year of publication, (3) study purpose, (4) number of participants, (5) CT feature utilized, (6)

title, (7) prediction performance/statistical measure used for evaluation, (8) input feature, and (9) prediction outcome. All data were extracted by a single author (OE). The primary outcome was the performance of radiologic abdominal wall features in predicting surgical outcomes.

Quality of Evidence and Risk of Bias

A quantitative analysis was deemed inappropriate due to the heterogeneity in surgical application as related to the outcomes measured and comparison features. A qualitative synthesis, in the form of a narrative review, was carried out to assess the results and risk of bias on outcome. The Newcastle-Ottawa Quality Assessment Scale was used to score the quality of articles included.¹³

RESULTS

A total of 1922 articles were returned on initial search of the described databases. Following removal of duplicates, 1904 remained (Fig. 1). Screening at the level of title and abstract resulted in 106 articles being included for a full-text review. A full manuscript review was conducted on the remaining articles, resulting in 12 articles found to be appropriate and included in the systematic review. Years of publication ranged from 2011 to 2020, with over one-third published after 2019 (Fig. 2). The median number of patients included was 93 (IQR ± 287).

Study Purpose and Feature Characteristic

Of the 12 included articles, 11 made predictions based on CT features (Table 1), which we organized based on the ability to either predict postoperative complications (n = 9) or the need for intraoperative intervention (n = 3). Each radiologic feature was further categorized as belonging to one of the following metrics: distance (n = 28), area (n = 9), volume (n = 10), ratio (n = 6), or other (n = 5) (Table 2). The top 3 most frequently used features were hernia volume (n = 9), subcutaneous fat volume (n = 5), and defect size (n = 8).

Outcomes Obtained Utilizing CT Features

All studies used anatomical properties to predict surgical outcomes from CT images (Table 2). We categorized these outcomes into postoperative complications and need for surgical intervention. Postoperative complications were reported in 9 studies. The 2 most commonly reports outcomes were surgical site infection (SSI) (n = 4) and hernia recurrence (n = 3). Surgical interventions were obtained by 4 articles, including risk of emergent laparotomy (n = 1) and need for component separation or myofascial release (n = 3). Seventy-five percent (n = 9) of included papers reported an odds ratio. Thirty-three percent (n = 4) of included papers reported area under the curve (AUC). Median AUC and odds ratio were 0.68 (±0.16) and 1.12 (±0.39), respectively. Love et al. study alone reported accuracy (mean 76.9, SD ± 0.83). The top 5 odds ratios included the following CT features: hernia neck ratio > 2.5 (53.24 [CI 12.77–345.20]), IH volume/peritoneal volume ratio <



No. publications per year

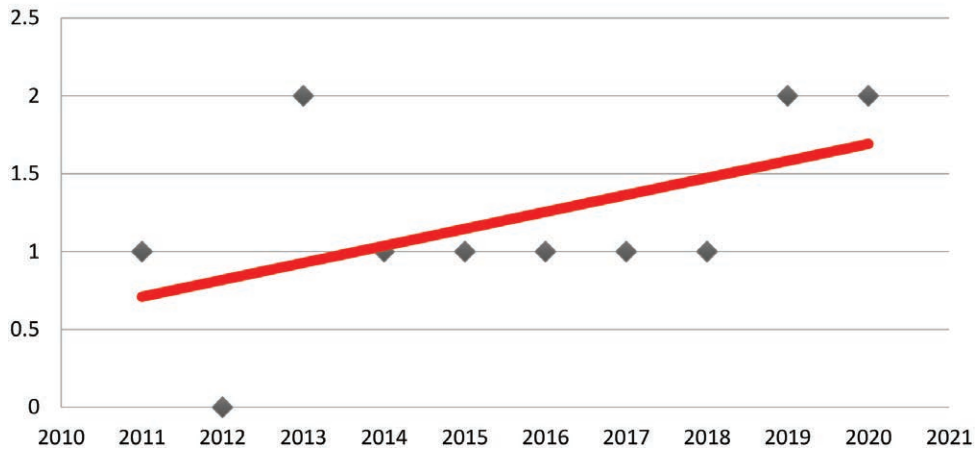


Fig. 1. Number of manuscripts published per year.

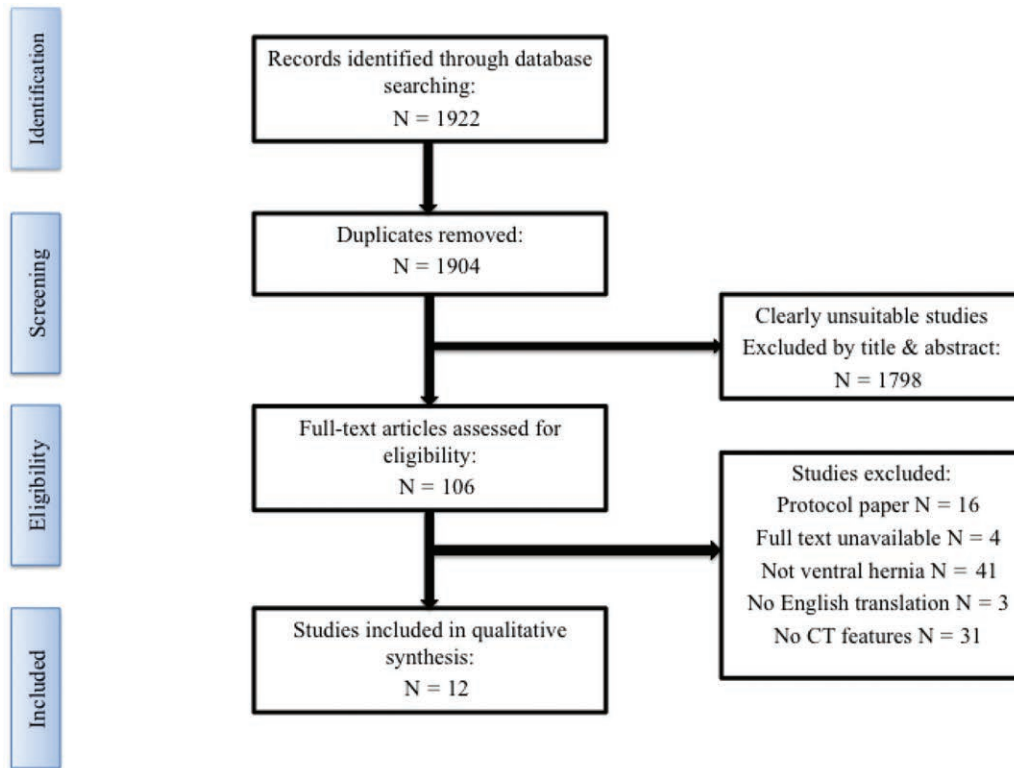


Fig. 2. PRISMA (Preferred Items for Systematic Reviews and Meta-Analyses) flow chart of study selection.

20% (35 [CI 1.38–888]), hernia angle (6.12 [CI 2.24–20.00]), psoas muscle Hounsfield unit average calculation (5.313 [CI 1.121–25.174]), and rectus thickness (3.87 [CI 0.51–29.41]). The top 5 predictive CT feature models were hernia neck ratio > 2.5 (AUC 0.90), rectus width (AUC 0.83), component separation index (AUC 0.79), subcutaneous fat area (AUC 0.69), and sarcopenia based on gender-specific quartiles (AUC 0.67).

Quality Assessment of Studies Included in the Review

A summary and comparison of quality across studies using the Newcastle-Ottawa Quality Assessment Scale is outlined in Table 3. Eight of 12 studies were of “good” quality, receiving a total score of at least 6 of 8 across all domains.^{11,14–20} The remaining 4 studies were of “poor” quality due to no comparative analysis built into the study design.^{6,21–23} No study had a total score < 4.

Table 1. Study Purpose

Year	Author	Relevant Purpose	Data Type	N	Relevant Findings/Outcome
2011	Sabbagh et al	Investigation of volume measurements as a predictive factor for tension-free fascial closure	Patient age and BMI, the IH's width, length and surface area, and the IH volume/peritoneal volume ratio	17	The IH volume/peritoneal volume ratio is predictive of tension-free fascia closure for hernias or IHs with loss of domain
2013	Franklin et al	Examination of preoperative CT to provide insight into variabilities that may allow for prediction of abdominal closure with component separation techniques	Preoperative CT, transverse defect size, defect area, and percent abdominal wall defect	54	Preoperative determination of abdominal wall defect ratios and hernia defect areas may represent a more accurate method to predict abdominal wall closure after CST
2014	Levi et al	Evaluation of whether tissue morphology measurements (morphometrics) of preoperative CT scans stratify the risk of surgical site infection in patients undergoing ventral hernia repair with a component separation technique	Routine preoperative CT	93	Subcutaneous fat area, total body circumference had increased odds ratios for surgical site infection ($P=0.004$, 0.014 , and 0.012 , respectively), indicating that these measures are better associated with surgical site infection than body mass index
2015	Aquina et al	Investigation of the relationship among different obesity measurements and the risk of IH	Preoperative CT scans were used to measure visceral fat volume, subcutaneous fat volume, total fat volume, and waist circumference	193	Visceral obesity, history of inguinal hernia, and location of specimen extraction site are significantly associated with the development of an IH, whereas BMI is poorly associated with hernia development
2015	Blair et al	Evaluation of the relationship of CT measurements of ventral hernia defect size and abdominal wall thickness, as it correlates with postoperative complications and need for complex abdominal wall reconstruction	Preoperative abdominal CT imagining	151	Preoperative CT measurements of hernia defects and abdominal wall thickness predict wound complications and the need for complex abdominal wall reconstruction techniques. Hernia recurrence was not predicted by abdominal wall thickness or defect size
2016	Fueter et al	To determine whether morphological characteristics are associated with the occurrence of complications.	Size of the hernia and the size of the neck were measured based on operative reports, ultrasound, and CT or MRI images	106	Umbilical hernia with HNR [2.5] should be operated on, irrespective of the presence of symptoms (91% sensitivity and 84% specificity)
2017	Mueck et al	Identifying radiographic features of ventral hernias associated with increased risk of bowel incarceration	CT scans were reviewed to determine hernia characteristics	352	Taller height and smaller angle are associated with the need for emergent repair. Early elective repair should be considered for patients with hernia features concerning for increased risk of bowel compromise
2018	Barnes et al	Determination of the ability of an independent parameter to predict postoperative morbidity following ventral hernia repair	Preoperative abdominal CT. Sarcopenia was determined using the Hounsfield unit average calculation—a measure of psoas muscle size and density	58	Preoperative sarcopenia was associated with an increased risk for postoperative complications
2019	Van Rooijen et al	Investigation of whether a relation between sarcopenia and IH exists	CT examinations performed within 3 months preoperatively were used to measure the skeletal muscle index	283	Sarcopenia does not seem to be a risk factor for the development of an IH
2019	Winters et al	Determining the predictability of reherniation and surgical site infections using preoperative CT measurements	Preoperative CT scan available. Visceral fat volume, subcutaneous fat volume, loss of domain, rectus thickness and width, abdominal volume, hernia sac volume, total fat volume, sagittal distance, and waist circumference	65	Visceral fat volume, subcutaneous fat volume, and hernia sac volume derived from CT scan measurements may be used to predict reherniation and surgical site infections in patients undergoing complex ventral hernia repair using CST
2019	Schlusser et al	Examination of multiple markers' interaction of adiposity and hernia size in open ventral hernia repair	Preoperative CT imaging. Abdominal subcutaneous fat, intra-abdominal volume, hernia volume, and ratio of hernia volume to intra-abdominal volume (representing visceral eventration)	1178	Values of hernia area, volume, intra-abdominal volume, ratio of hernia volume to intra-abdominal volume, BMI, and Abdominal subcutaneous fat are collinear markers of patient obesity and hernia proportions
2020	Love et al	Predicting the need for additional myofascial release preoperatively using CT	Preoperative CT scan	342	The rectus width to hernia width ratio is a practical and reliable tool to predict the ability to close the defect during open Rives–Stoppa ventral hernia repair without additional myofascial release. An rectus width to hernia width ratio of >2 portends fascial closure with rectus abdominis myofascial release alone in 90% of cases

CST, component separation techniques; HNR, hernia-neck ratio.

Table 2. CT Radiologic Features and Outcomes

Author	Outcome Measure	Subgroup	Radiologic Features	Area Under Curve (CI)	Odds Ratio (CI)		
Sabbagh et al (2011)	Tension-free closure	Area	IH surface area (cm ²)	NA	1 (0.98–1.02)		
		Ratio	IH volume/peritoneal volume ratio < 20%	NA	35 (1.38–888)		
Franklin et al (2013)	Postoperative complication	Distance	Defect length (cm)	NA	0.90 (0.81–1.01)		
			Defect length (cm)	NA	0.78 (0.65–0.93)		
			Rectus width	NA	1.14 (0.75–1.75)		
		Ratio	Rectus thickness	NA	3.87 (0.51–29.41)		
			Rectus thickness	NA	2.06 (0.21–19.83)		
			Rectus width	NA	0.91 (0.64–1.30)		
			Abdominal wall/pannus circumference	NA	2.21 (0.00006–85263.18)		
			Abdominal wall thickness	NA	1.31 (0.63–2.73)		
			Intra-abdominal/pannus volume	NA	1.10 (0.28–4.26)		
		Area	Abdominal wall volume/defect area	NA	1.01 (1.00–1.03)		
			Defect area (cm ²)	NA	1.00 (0.99–1.00)		
			Pannus area	NA	1.00 (0.99–1.00)		
		Distance	Intra-abdominal area	NA	0.99 (0.98–1.00)		
			Abdominal wall circumference	NA	0.95 (0.89–1.01)		
			Pannus circumference	NA	0.95 (0.89–1.01)		
Levi et al (2014)	Surgical site infection	Distance	Pannus thickness	NA	0.91 (0.55–1.53)		
		Area	Xiphoid-pubis length	NA	0.82 (0.60–1.14)		
		Area	Body circumference (per 10 cm)	0.654	1.59 (1.11–2.28)		
Aquina et al (2015)	Postoperative IH	Ratio	Total body area (per 100 cm ²)	0.646	1.31 (1.06–1.62)		
		Volume	Subcutaneous fat (per 100 cm ²)	0.685	1.89 (1.23–2.91)		
		Volume	Visceral obesity	NA	NA		
		Volume	Visceral fat volume	NA	NA		
Blair et al (2015)	Postoperative complication	Ratio	Subcutaneous fat volume	NA	NA		
			Total fat volume	NA	NA		
			Waist circumference	NA	NA		
			PC2 (pubis, hip girdle, defect width, abdominal wall thickness umbilical, abdominal wall thickness retrorenal, retrorenal, and AW)	NA	1.038 (0.933–1.155)		
			PC1	NA	1.080 (1.01–1.160)		
	Need for component separation	Area	PC1	NA	1.00 (0.77–1.29)		
		Distance	PC2	NA	1.00 (0.66–1.51)		
		Ratio	Defect area	NA	NA		
		Ratio	Defect width	NA	NA		
		Ratio	PC2	NA	1.159 (1.03–1.3)		
Fueter et al (2016)	Postoperative complication	Ratio	PC1	NA	0.960 (0.89–1.04)		
Mueck et al (2017)	Risk of small bowel incarceration	Distance	Hernia neck ratio > 2.5	0.9038	53.24 (12.77–345.20)		
			Width	NA	1.01 (.87–1.16)		
		Other	Sac height	NA	1.44 (1.24–1.68)		
Barnes et al (2018)	Postoperative morbidity	Other	Angle	NA	3.07 (1.14–9.95)		
			Angle	NA	6.12 (2.24–20.00)		
Van Rooijen et al (2019)	Postoperative complication	Other	Hounsfield unit average calculation	NA	5.313 (1.121–25.174)		
			Distance	Model 2 (sarcopenia based on literature cut-offs)	0.6538	1.52 (0.76–3.12)	
				Model 3 (model 3 with sarcopenia as lowest gender-specific quartile)	(0.5703–0.7330)	2.08 (0.89–4.79)	
		Model 3 (model 3 with sarcopenia as lowest gender-specific quartile)		0.6670	2.08 (0.89–4.79)		
		Distance	Rectus thickness	(0.5787–0.7521)	NA	1.46 (0.66–3.20)	
			Rectus width	NA	NA	1.13 (0.81–1.58)	
			Sagittal distance	NA	NA	1.05 (0.86–1.28)	
		Ratio	Defect size	NA	NA	1.00 (0.99–1.01)	
			Waist circumference	NA	NA	0.96 (0.28–1.09)	
			Loss of domain	NA	NA	1.39 (0.93–1.75)	
		Volume	Hernia sac volume	NA	NA	1.41 (0.92–2.16)	
			Abdominal volume	NA	NA	0.91 (0.71–1.19)	
			Abdominal volume	NA	NA	0.91 (0.71–1.19)	
		Winters et al (2019)	Postoperative complication	Distance	Rectus thickness	NA	3.26 (0.42–25.24)
					Rectus width	NA	1.23 (0.75–2.03)
Waist circumference	NA				1.23 (0.63–2.02)		
Ratio	Sagittal distance			NA	1.08 (0.91–1.27)		
	Defect size			NA	0.99 (0.99–1.00)		
	Loss of domain			NA	0.41 (0.16–1.09)		
Volume	Visceral fat volume			NA	0.72 (0.41–1.25)		
	Subcutaneous fat volume			NA	0.31 (0.12–0.81)		
	Abdominal volume			NA	1.42 (0.82–2.44)		
	Subcutaneous fat volume			NA	1.29 (0.81–2.09)		
Volume	Total fat volume	NA	1.27 (0.93–1.74)				
	Subcutaneous fat volume	NA	1.29 (0.81–2.09)				
Volume	Hernia sac volume	NA	1.15 (1.04–1.27)				

(Continued)

Table 2. (Continued)

Author	Outcome Measure	Subgroup	Radiologic Features	Area Under Curve (CI)	Odds Ratio (CI)	
Schlosser et al (2019)	Postoperative complication	Area	Hernia sac area	NA	1.11 (0.97–1.23)	
			Volume	Intra-abdominal volume	NA	0.9 (0.74–1.10)
				Intra-abdominal volume	NA	0.9 (0.74–1.10)
		External abdominal volume		NA	1.09 (0.97–1.22)	
		Need for component separation	Volume	Hernia sac volume	NA	1.18 (1.08–1.30)
				External abdominal volume	NA	1.18 (1.06–1.32)
				Intra-abdominal volume	NA	1.04 (0.86–1.26)
				External abdominal volume	NA	0.98 (0.84–1.15)
				Intra-abdominal volume	NA	0.85 (0.65–1.11)
				Intra-abdominal volume	NA	1.18 (0.99–1.42)
		Need for panniculectomy	Volume	External abdominal volume	NA	1.02 (0.92–1.22)
				Hernia volume	NA	1.34 (1.21–1.49)
				Hernia volume	NA	1.52 (1.37–1.69)
		Failure of fascial closure	Volume	External abdominal volume	NA	1.33 (1.20–1.48)
				Intra-abdominal volume	NA	1.09 (0.91–1.31)
Intra-abdominal volume	NA			1.20 (0.92–1.57)		
Love et al (2020)	Need for myofascial release	Distance	Rectus width	0.83	NA	
			Other	0.798	NA	
				Component separation index		

AW, abdominal wall.

DISCUSSION

At its worst, ventral hernia progresses to a chronic, predictable cycle of hernia repair followed by recurrence, with each subsequent repair being more complex than the previous. Due to the increasing complexity of repairs, there is a need to optimize preoperative assessment, surgical planning, and patient counseling. Traditionally, CT imaging has been used mainly to confirm the physical exam finding suspicious for hernia formation. However, with improved CT image resolution and the advent of image-processing software in the last decade, advanced image analysis has emerged as a potential tool used for predicting outcomes. To our knowledge, this is the first systematic review of radiographic features associated with outcomes of abdominal wall reconstruction. Included studies were of high quality for a growing area of research. In summary, we demonstrate that a variety of radiographic features, most commonly hernia volume, subcutaneous fat volume, and defect size, are used to predict either postoperative complications or the need for intraoperative intervention. Overall, advanced image processing is a useful, practical tool with potential to augment decision-making in the preoperative phase.

Image analysis of subcutaneous fat volume, a commonly identified feature, has provided a deeper understanding on obesity as a risk factor for adverse outcomes. Following IH repair, obese patients are more likely to develop complications, specifically SSI and recurrence.^{24,25} Traditionally, body mass index (BMI) has been used as a marker for obesity. While BMI may partially predict obesity-related complications after surgical intervention, this measure does not account for patient-specific fat distribution within the abdominal cavity. Using advanced analysis of radiographic images, surgeons have been able to identify and study patient-specific obesity measures, such as subcutaneous fat volume. Schlosser et al. showed that in addition to BMI, subcutaneous fat volume was a collinear marker of obesity.²⁰ Several studies have elucidated the discrete influences that subcutaneous fat volume and

other patient-specific obesity features have on outcomes. In patients undergoing colorectal surgery, visceral obesity was associated initial formation of IH.¹⁷ In patients undergoing component separation, visceral fat volume was a significant predictor of recurrence.⁶ Subcutaneous fat, specifically, has been demonstrated as an independent risk factor for SSI.^{6,26} In fact, subcutaneous fat was a better predictors of SSI compared with BMI.¹⁶ Although we inform obese patients of their increased risk for complications, we are unable to tell them how much their risk is increased based on patient-specific obesity measures, including abdomen size and subcutaneous fat volume. Identification of patient-specific obesity measures using advanced imaging analysis will not only allow for better outcome prediction, but also improve patient counseling.

Advanced analysis of radiologic hernia-specific measures is a promising but understudied method of predicting recurrence. To date, risk factor analysis for recurrence has focused primarily on past medical history and comorbidities, such as smoking, obesity, and number of previous recurrences. While surgeons use CT scans to confirm the presence of a hernia, use of hernia-specific measures to predict recurrence is not a standard of surgical care, likely due to the paucity of research in this area. Although recurrence was the most commonly predicted outcome in the present study, only a few included studies identified hernia-specific radiographic features related to this outcome, and their findings did not align. Hernia defect area was associated with increased recurrence in patients undergoing component separation.¹⁵ Similarly, DiCocco et al. found that recurrent hernias had increased preoperative defect areas, but the difference was not statistically significant.⁷ However, contradicting these findings, recurrence did not correlate with any CT measurements of the abdominal wall, including hernia defect size.²¹ Since recurrence is a hallmark of chronic, unrelenting IH disease, research is needed to understand how radiographic features may be used to predict recurrence

Table 3. Newcastle-Ottawa Quality Assessment Scale

Study	Selection			Demonstration that outcome of interest was not present at start of the study (maximum: ★)	Comparability		Outcomes		Total score
	Representativeness of exposed cohort (maximum: ★)	Selection of non-exposed cohort (maximum: ★)	Ascertainment of exposure (maximum: ★)		Comparability of cohorts on the basis of design or analysis (maximum: ★★)	Assessment of outcome (maximum: ★)	Follow-up long enough for outcomes to occur (maximum: ★)	Adequacy of follow up of cohorts (maximum: ★)	
Sabbagh et al (2011)	★	—	★	★	★	★	★	★	★
Franklin et al (2013)	★	★	★	★	★	★	★	★	★
Levi et al (2014)	★	—	★	★	★	★	★	★	★
Aquina et al (2015)	★	—	★	★	★	★	★	★	★
Blair et al (2015)	★	—	★	★	—	★	★	★	★
Fueter et al (2016)	★	—	★	★	—	★	★	★	★
Mueck et al (2017)	★	—	★	★	—	★	★	★	★
Barnes et al (2018)	★	—	★	★	—	★	—	—	★
Van Rooijen et al (2019)	★	—	★	★	—	★	—	—	★
Winters et al (2019)	★	—	★	★	—	★	—	—	★
Schlosser et al (2019)	★	★	★	★	★	★	★	★	★
Love et al (2020)	★	★	★	★	★	★	★	★	★

*Good quality: 3 or 4 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain. Fair quality: 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain. Poor quality: 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome/exposure domain.

Radiologic imaging has great potential to enhance surgical planning. In the preoperative phase, it is important to assess the ability to achieve fascial closure with a given surgical technique. Christy et al. demonstrated the efficacy of a novel component separation index in preoperatively predicting the difficulty of achieving fascial closure²⁷ Similarly, Love et al. demonstrated that the rectus width to hernia width ratio is a practical, reliable tool to predict the ability to close during Rives–Stoppa repair without abdominal muscle release.¹¹ In large IHs with loss of domain, volume to peritoneal volume ratio of <20% was predictive of tension-free fascial closure.¹⁴ The software used to calculate volumes in this study was specialized with limited accessibility. However, Martre et al. presented a standardized volumetric analysis technique that any surgeon with basic computer skills and radiological knowledge can perform in the clinic in an autonomous, fast manner.⁹ Preoperatively determining the likelihood of achieving fascial approximation with component separation is increasingly important because bridging biologic mesh for IH has yielded poor outcomes.²⁸ Despite the demonstrated potential for CT imaging to guide surgical planning, it is rarely used, as confirmed by a systematic review.²⁹

This systematic review has limitations. The quality of any review is determined by that of its constituent studies. For a new, growing area of research, the quality of reporting across included studies was satisfactory, but not many studies were available. Advanced image analysis in radiographic features has not yet become a mainstay of preoperative assessment in abdominal wall reconstruction. Therefore, key considerations such as cost and patient-reported outcomes, which will be crucial in determining the true advantage of this technology, have not yet been assessed in the literature. More importantly, the included studies were heterogeneous, with a variety of target radiographic features, feature-specific measures, postoperative outcomes, and advanced image analysis software. Such heterogeneity makes it difficult to synthesize results into a cohesive, definitive conclusion. In addition, the lack of formal standards for reporting on predictive performance of radiographic features in this new field made the quantitative assessment impossible. Finally, this systematic review is subject to selection bias, as researchers are more likely to publish on radiographic features that successfully predicted outcomes than those that did not.

With the exponential advancement in technological hardware and software, the future of computer-aided decision-making in abdominal wall reconstruction is promising. The authors envision the incorporation of 3D volumetric measurements, along with standard CT features, into multi-modal data (eg, labs, genomic, demographics) algorithms filtered through complex machine learning and neural networks models to help surgeons make informed decisions.

CONCLUSIONS

To our knowledge, the present study is the first systematic review of radiographic features associated with outcomes of hernia repair. In summary, we demonstrate that a variety of radiographic features, most commonly

hernia volume, subcutaneous fat volume, and defect size, are increasingly used to predict either postoperative complications or the need for intraoperative intervention. In the future, advanced image analysis of preoperative CT scans may be used to not only identify at-risk patients, but also customize surgical approaches to the patient's anatomy and comorbidities. Large, multicenter studies will better define the usefulness of CT measurements in the preoperative assessment of ventral hernia repair candidates.

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