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Outcomes and CT scan three-dimensional volumetric analysis of emergent paraesophageal hernia repairs: predicting patients who will require emergent repair

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Abstract

Introduction Elective repair versus watchful waiting remains controversial in paraesophageal hernia (PEH) patients. Generation of predictive factors to determine patients at greatest risk for emergent repair may prove helpful. The aim of this study was to evaluate patients undergoing elective versus emergent PEH repair and supplement this comparison with 3D volumetric analysis of hiatal defect area (HDA) and intrathoracic hernia sac volume (HSV) to determine risk factors for increased likelihood of emergent repair.

Methods A retrospective review of a prospectively enrolled, single-center hernia database was performed on all patients undergoing elective and emergent PEH repairs. Patients with adequate preoperative computed tomography (CT) imaging were analyzed using volumetric analysis software.

Results Of the 376 PEH patients, 32 (8.5%) were emergent. Emergent patients had lower rates of preoperative heartburn (68.8%vs85.1%, $p=0.016$) and regurgitation (21.9%vs40.2%, $p=0.04$), with similar rates of other symptoms. Emergent patients more frequently had type IV PEHs (43.8%vs13.5%, $p<0.001$). Volumetric analysis was performed on 201 patients, and emergent patients had a larger HSV (805.6 ± 483.5vs398.0 ± 353.1cm^3, $p<0.001$) and HDA (41.7 ± 19.5vs26.5 ± 14.7 cm^2, $p<0.001$). In multivariate analysis, HSV increase of 100cm^3 (OR 1.17 CI 1.02–1.35, $p=0.022$) was independently associated with greater likelihood of emergent repair. Post-operatively, emergent patients had increased length of stay, major complication rates, ICU utilization, reoperation, and mortality (all $p<0.05$). Emergent group recurrence rates were higher and occurred faster secondary to increased use of gastropexy alone as treatment ($p>0.05$). With a formal PEH repair, there was no difference in rate or timing of recurrence.

Conclusions Emergent patients are more likely to suffer complications, require ICU care, have a higher mortality, and an increased likelihood of reoperation. A graduated increase in HSV increasingly predicts the need for an emergent operation. Those patients presenting electively with a large PEH may benefit from early elective surgery.

Keywords Paraesophageal Hernia · Hiatal Hernia · Emergency · Volumetric analysis · Fundoplication · Hernia

Paraesophageal hernias (PEH) are defined by a laxity of the phrenoesophageal ligament that allows for herniation of a peritoneal sac and abdominal viscera into the mediastinum. They are a subtype of hiatal hernia categorized as type II–IV based on the absence (type II) or presence (type III) of a concurrent herniated gastroesophageal junction, and the presence of abdominal structures other than the stomach in the hernia sac (type IV) [1]. Incidence of all PEH (type I–IV) in the general population is difficult to ascertain due to many patients being asymptomatic, but it is believed to be a common occurrence with estimates ranging anywhere from 10 to 80% [2, 3]. Symptoms can vary widely, with many

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being mechanical in nature, such as heartburn, regurgitation, weight loss, chest/epigastric pain, dyspnea, and gastric obstruction; however, PEH can also cause anemia secondary to ulceration at the thoracic outlet or within the herniated stomach [4].

While many patients may only have mild symptoms, there are feared complications of a PEH that have previously led surgeons to strongly consider early operation for all PEH. These complications include volvulus or incarceration, leading to obstruction, ischemia, or perforation. Early literature reported that up to 30% of patients undergoing non-operative management of a minimally symptomatic PEH develop acute symptoms. Mortality for patients with acute symptoms requiring emergent intervention was cited as high as 50% [5–8]. For this reason, repair of all paraesophageal hernias was historically recommended regardless of symptoms.

The twenty-first century has brought about new well-designed studies that suggest patient's with asymptomatic type III PEH are actually less likely develop acute symptoms than previously thought. Stylopoulus et al. performed an analysis of available data in 2002 and found an annual risk of 1.16%; the authors also performed a Markov Monte Carlo analysis, with the simulation finding that watchful waiting was the most beneficial strategy in 83% of patients over the age of 65. Included in their analysis was updated data related to mortality in emergent surgery, finding rates of 5.4% (versus 1.38% for elective laparoscopic hernia repair), lower than previously described [9]. Jung et al. revisited this model by incorporating recent data regarding elective laparoscopic hernia repairs. Both studies concluded that watchful waiting was the superior strategy for roughly 4 out of 5 patients [10].

Despite a recent paradigm shift towards watchful waiting, the ideal management strategy remains unclear in asymptomatic patients, and the literature has yet to describe specific patients who may benefit most from early repair in the symptomatic or asymptomatic population. This view is driven by decreased morbidity and mortality in select patients who undergo elective intervention [11–14].

Volumetric analysis of computed tomography (CT) imaging has previously proven useful in preoperative evaluation of PEH patients [15], however, has not been utilized to evaluate whether patients may require emergent surgery or benefit from elective surgery. The aim of the present study was to compare the presentation and outcomes of emergent and non-emergent PEH patients, and to further supplement this analysis with preoperative CT imaging using three-dimensional volumetric analysis in order to determine factors associated with requiring an emergent operation.

Materials and methods

Patient selection

After obtaining approval from the Institutional Review Board of Carolinas Medical Center, 10 years of data were retrospectively reviewed from a single-institution hernia-specific database (January 2008–July 2018). Patient and hernia characteristics, operative details, and outcomes were obtained from the database. Patients were only included in the volumetric analysis if they had preoperative computer tomography (CT) scans of adequate quality for this analysis. Adequate images were defined as visualizing the entirety of the crural defect and hernia sac. The primary outcome of this study was the requirement of emergency surgery. Secondary outcomes were post-operative complications, length of stay, hernia recurrence, and volumetric measurements. Major complications were defined as Clavien-Dindo Grades III, IV, and V [16].

3-Dimensional volumetric analysis

CT images were obtained from the Carolinas Medical Center Picture Archiving and Communication System (iSite PACS version 3.6.120.0, Philips healthcare Informatics, Foster City, CA). As previously described, images were analyzed using specialized volumetric software (Aquarius iNtuition, TeraRecon, San Mateo, CA) [15, 17]. The HDA was measured using a single-rotated cross-sectional image, which included both crura, mimicking the surgeons view during a laparoscopic PEH repair. The HSV was measured by manually outlining the hernia sac on all axial images containing the hernia, which the software utilized to calculate HSV [15]. CT measurements were performed by a single surgeon and verified independently by two additional surgeons.

Statistical analysis

Descriptive statistics are reported as means with the corresponding standard deviations for continuous variables, and percentages for categorical variables. Pearson's Chi-squared tests and Fisher's exact tests were used to analyze categorical variables. Wilcoxon–Mann–Whitney and Kruskal–Wallis tests were used to analyze continuous and ordinal variables. Multivariate logistic regression modeling was used to analyze factors potentially associated with emergent operation, controlling for preoperative heartburn, regurgitation, nausea/vomiting, dysphagia, early satiety, and retrosternal chest pain, as well as hernia type, HDA and HSV. Multivariate logistic regression was also utilized to evaluate for factors associated with recurrence. Statistical significance was set

at $p \leq 0.05$, and all reported p-values are two tailed. Data were analyzed using Statistical Analysis Software, version 9.3 (SAS Institute, Inc., Cary, NC).

Results

In total, 376 patients underwent PEH repair with a mean age of 64.3 ± 12.3 years (64.1 ± 12.1 years for elective cases versus 66.1 ± 14.1 years for emergent, $p = 0.369$). Emergent repairs were required in 32 cases (8.5%). The majority of patients were female (73%). At presentation, emergent patients had a lower BMI (25.5 ± 5.5 kg/m^2) than elective patients (29.4 ± 5.0 kg/m^2, $p < 0.001$). Comorbidities were similar between groups (all $p > 0.05$), as were American Society of Anesthesiologist (ASA) scores ($p > 0.05$) (Table 1).

Preoperative symptoms varied significantly between the groups (Table 2). Emergent patients were less likely to have experienced heartburn (68.8% vs 85.1%, $p = 0.016$) or regurgitation (21.9% vs 40.2%, $p = 0.042$). The remainder of assessed preoperative symptoms, as well as the rate of Cameron's ulcers, were similar between the groups (all $p > 0.05$).

Hernia and operative characteristics are also presented in Table 2. Overall the majority of PEHs were type III hernias, followed by type IV and type II hernias. The emergent group had lower rates of type III hernias compared to the elective group, and much higher rates of type IV hernias ($p < 0.001$). Surgical approach was similar ($p > 0.05$), with the vast majority of patients in both groups undergoing laparoscopic procedures, and similar rates of patients requiring a conversion to an open procedure. Fundoplication rates were much lower in the emergent group (31.3% vs 75.6%, $p < 0.001$); however, when a fundoplication was performed, the rates of fundoplication types were all similar ($p > 0.05$). Emergent procedures were much more likely to undergo a salvage gastropexy (31.3% vs 4.1%, $p < 0.001$), which was defined as hernia sac resection and multiple anterior gastropexy fixation points with no or minimal hiatal closure, often due to the size of the hiatal defect. There were only two unplanned resections performed, both in emergent patients: one hemicolectomy for an ischemic segment of colon within the hernia, and the other gastrectomy for an ischemic stomach. Operative time was significantly lower in the emergent group as well, with emergent procedures taking approximately 40 min less than elective procedures on average ($p = 0.01$).

Post-operatively (Table 3), emergent patients suffered much higher rates of major complications (25.0% vs 5.2%, $p < 0.001$). Emergent patients were also more likely to require ICU admission during their hospitalization (50.0% vs 11.2%, $p < 0.001$), and had four days longer length of stay (LOS) on average ($p < 0.001$). Thirteen patients required return to the operating room within 30 days of their initial operation (3.5%), and those patients were more likely to have presented emergently (18.8% vs 2.1%, $p < 0.001$). Reasons for return to the operating room included six acute reherniations and one of each of the following: gastric outlet obstruction, gastrotomy repair, gastric volvulus, small bowel obstruction, wound dehiscence, gastropexy suture removal, and epidural abscess drainage. The emergent group also had a higher in-hospital mortality (6.3 vs 0.3%, $p = 0.021$). As

Table 1 Patient characteristics

	Total ($n = 376$)	Elective ($n = 344$)	Emergent (v$n = 32$)	p value
Age, years	64.3 ± 12.3	64.1 ± 12.1	66.1 ± 14.1	0.369
Female	72.9%	73.8%	62.5%	0.168
BMI, kg/m^2	29.1 ± 5.2	29.4 ± 5.0	25.5 ± 5.5	**< 0.001**
Comorbidity				
Congestive heart failure	6.4%	6.1%	9.4%	0.444
COPD	10.1%	10.1%	9.4%	1.000
CVA with deficit	2.9%	3.2%	0.0%	0.609
Diabetes Mellitus	12.5%	12.2%	15.6%	0.575
History of MI	5.6%	5.2%	9.4%	0.327
Peripheral vascular disease	4.2%	4.1%	6.3%	0.692
ASA Score				0.079
I	1%	0.7%	4.0%	
II	46.2%	47.5%	32.0%	
III	49.5%	48.9%	56.0%	
IV	3.3%	2.9%	8.0%	

Significant $p < 0.05$ value is given in bold

BMI Body Mass Index, *COPD* chronic obstructive pulmonary disease, *CVA* cerebrovascular accident, *MI* myocardial infarction, *ASA* American Society of Anesthesiologists

Table 2 Hernia and operative characteristics

	Total ($n=376$)	Elective ($n=344$)	Emergent ($n=32$)	p value
Preoperative symptoms				
Heartburn	88.7%	85.1%	68.8%	**0.016**
Dysphagia	46.9%	48.4%	31.3%	0.063
Retrosternal chest pain	62.0%	60.7%	50.0%	0.238
Early satiety	21.9%	22.3%	18.8%	0.644
Regurgitation	39.0%	40.2%	21.9%	**0.042**
Nausea/vomiting	32.4%	33.4%	21.9%	0.182
Cameron's ulcer	18.0%	19.1%	6.3%	0.069
PEH type				**< 0.001**
II	13.1%	13.4%	9.4%	
III	70.9%	73.1%	46.9%	
IV	16.0%	13.5%	43.8%	
Recurrent Hernia	21.5%	21.2%	25.0%	0.619
Surgical approach				0.814
Laparoscopic	91.5%	91.3%	93.8%	
Robotic	5.1%	5.2%	3.1%	
Open	1.3%	1.5%	0.0%	
Conversion	2.1%	2.0%	3.1%	
Fundoplication	71.48%	75.6%	31.3%	**< 0.001**
Type of fundoplication				0.785
Dor	1.5%	1.6%	0.0%	
Nissen	37.2%	37.5%	30.0%	
Toupet	61.3%	60.9%	70.0%	
Mesh placement	59.8%	61.1.%	46.9%	**0.118**
Salvage gastropexy	6.4%	4.1%%	31.3%	**< 0.001**
Operative time, min	203.4 ± 71.5	206.9 ± 68.6	168.6 ± 90.5	**0.010**

Significant $p < 0.05$ values are given in bold

PEH Paraesophageal Hernia

Table 3 Post-operative outcomes

	Total ($n=376$)	Elective ($n=344$)	Emergent ($n=32$)	p value
Length of Stay, days	3.9 ± 4.5	3.5 ± 3.3	7.6 ± 10.6	**< 0.001**
Major Complication	6.9%	5.2%	25.0%	**< 0.001**
ICU Admission	14.5%	11.2%	50.0%	**< 0.001**
Return to OR, 30 days	3.5%	2.1%	18.8%	**< 0.001**
Mortality	0.8%	0.3%	6.3%	**0.021**
Readmission, 30 days	8.6%	8.8%	9.4%	0.754
Hernia Recurrence	20.6%	19.3%	35.7%	**0.039**
Time to Recurrence, months	25.8 ± 23.9	28.5 ± 24.0	8.1 ± 14.5	**0.005**
Follow-up, months	39.9 ± 38.5	40.5 ± 39.2	33.8 ± 30.0	0.603

Significant $p < 0.05$ values are given in bold

ICU Intensive Care Unit, *OR* Operating Room

expected, given the much higher salvage gastropexy rates, emergent hernias had a higher risk of hernia recurrence (35.7% vs 19.3%, $p=0.039$) and those recurrences were identified much sooner (8.1 ± 14.5 vs 28.5 ± 24.0 months, $p=0.005$).

When excluding the patients who required salvage gastropexy, hernia recurrence rates were similar between emergent and elective patients (21.1% vs 17.8%, $p=0.758$), and emergent patients were not identified any sooner (6.8 ± 5.5 vs 29.3 ± 23.9 months, $p=0.091$).

Two hundred and one patients had preoperative CT imaging that was suitable for volumetric analysis, of whom 27 cases (13.4%) were emergent. For emergent cases, 11 patients (40.7) underwent CT imaging in the outpatient setting prior to emergent presentation, and the mean time from CT to surgery in this group was 61.5 ± 217.6 days. Volumetric measurements of this subset are reported in Table 4. The emergent patient group had larger mean HDA (41.7 ± 19.5 vs 26.5 ± 14.7 cm^2, $p < 0.001$) and larger HSV (805.6 ± 483.5 vs 398.0 ± 353.1 cm^3, $p < 0.001$).

In multivariate logistic regression analysis evaluating emergent repair (Table 5), no specific preoperative symptoms were independently associated with increased risk of requiring emergent surgery. Of the measurements obtained from imaging, HSV increase of 100 cm^3 was the only factor independently associated with emergent repair (OR 1.2 CI 1.023–1.346, $p = 0.022$). Emergent repair, hernia type, HDA, and HSV did not affect the risk of recurrence in a separate multivariate analysis.

Table 5 Multivariate analysis of emergent repair and hernia recurrence

	OR	CI 95%	*p* value
Emergent repair			
Reflux	0.913	0.304–2.734	0.872
Dysphagia	1.332	0.466–3.809	0.593
Retrosternal chest pain	0.603	0.224–1.620	0.316
Early satiety	0.928	0.292–2.945	0.899
Regurgitation	0.520	0.156–1.730	0.286
Nausea/vomiting	1.063	0.349–3.237	0.915
Type III Hernia	1.530	0.310–7.561	0.602
Type IV Hernia	0.782	0.121–5.069	0.796
HDA (5 cm^2)	1.162	0.995–1.356	0.057
HSV (100 cm^3)	**1.173**	**1.023–1.346**	**0.022**
Recurrence			
Emergent repair	2.160	0.746–6.248	0.155
Type III Hernia	1.121	0.380–3.305	0.835
Type IV Hernia	1.042	0.277–3.923	0.951
HDA (5 cm^2)	0.878	0.749–1.029	0.109
HSV (100 cm^3)	1.001	0.881–1.137	0.991

Significant $p < 0.05$ values are given in bold

OR Odds Ratio, *CI* confidence interval, *HDA* Hernia defect area, *HSV* Hernia Sac volume

Discussion

Delineating which patients will benefit most from an early elective PEH repair remains an unanswered question within surgical literature. With the increased utilization of CT imaging throughout healthcare, many patients presenting with PEH have CT imaging at the time of surgeon consultation. Utilizing this imaging to determine which patients can benefit from an early elective repair and lower the risk of an emergent presentation can be an important tool for surgeons.

This study demonstrates the significant difference in outcomes between elective and emergent PEH repairs, showing the importance of avoiding emergent repairs if possible. Emergent patients had higher rates of complications, longer length of stay, and earlier recurrence. Volumetric analysis has been demonstrated to be useful in the preoperative assessment of PEH patients. Analysis showed that patients with larger hernias were more likely to require complex techniques or bailout procedures [15]. Using these volumetric techniques to specifically analyze patients based on the need for emergent repair, increasing HSV was associated with increased risk for an emergency operation. For every increase in HSV of 100 cm^3, there is an over 20% increased odds of requiring an emergent repair. While volumetric analysis proves useful in determining the odds of requiring emergent repair, neither volumetrics nor hernia type or the need for emergent repair was associated with increased risk of recurrence.

The ability to predict which patients will require emergent surgery is important, because while many patients do well with watchful waiting, those who present emergently and undergo emergent repair are at a much higher risk of negative outcomes. This is supported by the present study and is consistent with prior literature on emergent PEH repair [9–11, 13, 14]. Emergent patients were at a much higher risk for increased LOS, ICU admission, return to the operating room, and mortality in this series. Poulose et al. evaluated over 1000 patients from the Nationwide Inpatient Sample (NIS), and found similar results, with emergent patients having a longer LOS, and a much higher mortality rate in emergent patients, at 15.7% versus 2.4% in the elective population ($p < 0.05$) [11]. Jassim et al. published a study also utilizing the NIS, which echoed the increased mortality associated

Table 4 Preoperative volumetric imaging analysis

	Total ($n = 201$)	Elective ($n = 174$)	Emergent ($n = 27$)	*p* value
HDA, cm^2	28.5 ± 16.2	26.5 ± 14.7	41.7 ± 19.5	**< 0.001**
HSV, cm^3	452.8 ± 397.1	398.0 ± 353.1	805.6 ± 483.5	**< 0.001**

Significant $p < 0.05$ values are given in bold

HDA Hernia defect area, *HSV* Hernia Sac volume

with emergent repair, as well as significantly increased overall morbidity [14]. Finally, Polomsky et al. reported that emergent patients again had higher mortality, and in multivariate analysis, emergent repair was a predictor of mortality, major complications, admission to the ICU, return to the operating room, and increased LOS [13]. The present study reiterates many of these findings, with emergent patients having increased LOS, higher mortality rates, and higher major complication rates. While these statistics are improved from very early surgical literature, they still highlight the importance of avoiding an emergent PEH repair, if possible, in regard to the significant morbidity and mortality.

The role of emergent repair on hernia recurrence is infrequently studied. The hernia recurrence rate in the present study was higher in the emergent group, and these patients were found to have a recurrence much faster. This is likely due to the technical differences in the operations, where emergent repairs were much more likely to forgo a fundoplication and more likely to undergo a salvage gastropexy. There was no difference in recurrence and time to recurrence between elective and emergent operations when patients underwent formal repair. Given this information, a formal repair should be performed whenever feasible and safe.

While watchful waiting versus elective repair remains debated between surgeons, there are certainly benefits to be had from avoiding an emergent PEH repair [18]. Many current guidelines, focusing on type III hernias, recommend watchful waiting for asymptomatic patients over the age of 65 and repair for symptomatic patients [1, 9, 10]. The present study differs in that it includes only patients who underwent surgery, and all but two of whom had symptomatic hernias. In this patient population, patients with larger HSV were more likely to require emergent surgery. In an asymptomatic patient, increased HSV may be a consideration to avoid watchful waiting, but this cannot be evaluated with the current patient cohort. However, in a symptomatic patient, larger HSV or increasing HSV may be indications to proceed with surgery in a more expeditious manner. Prediction tools for post-operative morbidity and mortality have been evaluated for patients undergoing PEH repair, but a common theme is that emergent operations significantly impact post-operative risk [19]. The gap in objective data to identify these high-risk patients who will present acutely and need an emergent operation can be filled by utilizing volumetric analysis. The authors are not proposing that preoperative CT become part of the preoperative work-up for PEH patients but do feel that it is a useful tool when obtained prior to consultation. If future studies demonstrate stronger relation of volumetrics to necessity of repair, CT scan may become indicated in the work-up of a subset of PEH patients.

While not practice changing at this point, this study demonstrates the potential utility of volumetrics in creating a model for predicting risk of requiring emergent PEH repair and may prove to be a basis for future analysis of hernia volume and its relation to emergent repair. A potential objective preoperative tool, such as one based on volumetrics, will be valuable, because as this study shows, symptomatology and hernia type alone do not adequately categorize patients into high and low risks groups for needing an emergent repair. Further studies volumetrically evaluating larger samples of emergent cases will be of benefit, as will prospective evaluations, for creating a functional predictive model. Furthermore, studies can evaluate change in hernia volume or defect size over time in patients who have multiple CTs performed to determine if increase in HDA or HSV leads to increased risk of emergent repair. Finally, time from CT imaging to surgery can be better standardized between the groups and may be aided by larger sample sizes where more patients have adequate preoperative imaging prior to repair.

This study is not without limitations. The foremost limitation is the wide range of times from CT imaging to surgery in the emergent group. While 40.7% of the emergent patients did have imaging available prior to their emergent presentation, this is not part of the standard work-up, which contributes to many of the emergent patients not having a CT until shortly before their operation. Presenting emergently may affect the volumetric measurements due to acute ongoing pathology, such as obstruction. Additionally, as a single-institution study at a large, tertiary medical center, the data may not translate universally across all types of facilities. Also limiting evaluation is a relatively low number of emergent cases included in the cohort. The study does not include asymptomatic patients who underwent watchful waiting, and impact of HSV size in nonoperative patients cannot be determined in the present study, as they were not included in the cohort. The rates of CT scan utilization may reflect selection bias in the volumetric analysis, as these patients may have presented with more severe symptoms leading to CT scan.

In conclusion, CT imaging and volumetric analysis can be useful tools in the preoperative assessment of patients with paraesophageal hernias in order to elucidate which patients are at higher risk for requiring an emergent operation in the future. Avoiding emergent PEH repair is the ultimate goal, due to the increased LOS, morbidity, and mortality.

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