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Computed Tomography Assessment of Gastric Band Slippage

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Keywords

Laparoscopic adjustable gastric banding · Slippage · Computed tomography · O sign · Gastric pouch

Abstract

Background: The purpose of this study was to develop and validate reliable computed tomography (CT) imaging criteria for the diagnosis of gastric band slippage. ***Material and Methods:*** We retrospectively evaluated 67 patients for gastric band slippage using CT. Of these, 14 had surgically proven gastric band slippage (study group), 22 had their gastric bands removed for reasons other than slippage (control group 1), and 31 did not require removal (control group 2). All of the studies were read independently by two radiologists in a blinded fashion. The "O" sign, phi angle, amount of inferior displacement from the esophageal hiatus, and gastric pouch size were used to create CT diagnostic criteria. Standard statistical methods were used. ***Results:*** There was good overall interobserver agreement for diagnosis of gastric band slippage using CT diagnostic criteria (kappa = 0.83). Agreement was excellent for the "O" sign (kappa = 0.93) and phi angle (intraclass correlation coefficient = 0.976). The "O" sign, inferior displacement from the hiatus >3.5 cm, and gastric pouch volume >55 cm^3 each had 100% positive predictive value. A phi angle <20° or >60° had the highest negative predictive value (NPV) (98%). Of all CT diagnostic criteria, enlarged gastric pouch size was most correlated with band slippage with an AUC of 0.991. ***Conclusion:*** All four imaging parameters were useful in evaluating for gastric band slippage on CT, with good interobserver agreement. Of these parameters, enlarged gastric pouch size was most correlated with slippage and abnormal phi angle had the highest NPV.

Introduction

Bariatric procedures are commonly performed for the treatment of morbid obesity and its associated comorbidities [1]. After the approval of laparoscopic adjustable gastric banding in 2001 by the Food and Drug Administration, laparoscopic adjustable gastric banding became the most frequently performed bariatric procedure accounting for 42% of bariatric procedures in 2008 [1, 2]. Adjustable gastric banding can be advantageous due to its low rate of early postoperative complications and mortality, minimal invasiveness, reversibility and adjustability, and decreased risk for vitamin/mineral deficiencies [3–6]. Reported long-term complications requiring surgical revision include band erosion, band slippage, late port infection, and esophageal dilatation from overconsumption with a reported mean onset time of 45 ± 30 months [5, 7, 8]. Of these complications, band slippage has been established as one of the most frequent, reported in 2%–36% of cases with a surgical revision rate ranging from 3.3% to 59.3% [4, 9]. Imaging has played a vital role in the diagnostic workup and detection of band slippage in the acute care setting.

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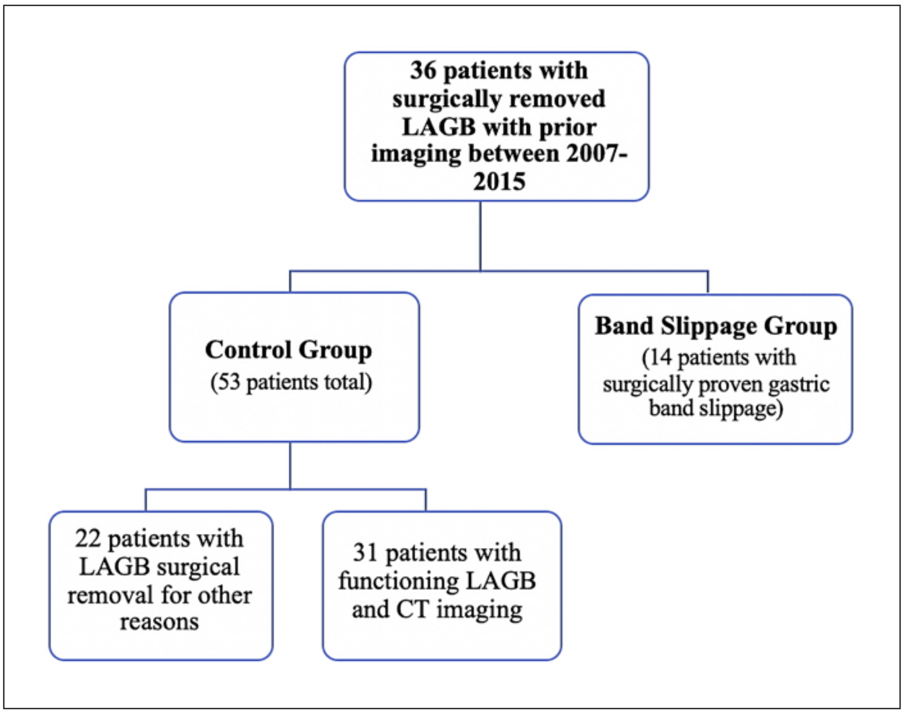

Fig. 1. Schema of patients included in the study.

Historically, the standard of care in patients with suspected complications from gastric banding has been upper GI series. One reason for this is there are no well-established criteria for band slippage on abdominal computed tomography (CT). Recent studies have shown a significant advantage of abdominal CT over upper GI series [10, 11]. The trend is moving toward CT now that low-dose CT protocols have been developed and optimized [11, 12].

Radiology literature has established several signs to indicate band slippage using abdominal radiographs, including the phi angle, the "O" sign, inferior displacement of the superolateral band margin from the diaphragm, and the presence of a dilated gastric pouch with an air-fluid level above the band [9, 13, 14]. Although the aforementioned imaging predictors have been well described on abdominal radiographs and fluoroscopy, corresponding imaging findings have not been evaluated on CT. Development of accurate CT imaging predictors may play a vital role in the detection of gastric band slippage, thus aiding in appropriate patient management and possibly surgical re-intervention. The purpose of this study was to develop and validate reliable CT imaging criteria for the diagnosis of gastric band slippage.

Materials and Methods

This study was approved by our hospital Institutional Review Board. The need for informed patient consent was waived because of the retrospective nature of the study. We utilized the "safe harbor" method to deidentify patient data. All studies and imaging analysis were performed in compliance with HIPAA regulations.

Patient Population

A retrospective search was conducted at our institution identifying patients with adjustable gastric bands reported by radiologists on all imaging modalities between 2007 and 2015. Included patients had a history of gastric band placement and prior abdominal or chest CT. Patients were excluded if they did not have visualization of a gastric band on abdominal or chest CT, if the gastric band was removed at an outside institution, or if the abdominal/chest CT was performed greater than 1.5 years prior to the gastric band removal.

Study Design: Study and Control Groups

Through a search of medical records and imaging reports and after application of the exclusion criteria, 189 patients with adjustable gastric bands were identified. Of these, 36 underwent surgery to evaluate the gastric band. Out of the 36 patients identified, 14 had surgically proven gastric band slippage and were designated as the study group. The study group patients each underwent preoperative abdominal CT to evaluate for abdominal pain, nausea, and/or vomiting and had surgical confirmation of gastric band slippage. The control group was composed of the remaining 22 patients who had their gastric bands removed for reasons other than slippage. Each of these had confirmed correct position of the gastric band at surgery and CT scan was performed for reasons unrelated to the gastric band within 3 months prior to the surgery. An additional 31 patients that had well-functioning gastric bands and CT scans, not requiring surgical revision, were selected to add to the control group (Fig. 1). Both the study and control group cases were randomized and placed into a single folder in the picture archive and communication system (PACS) and were subsequently read independently by two fellowship-trained body radiologists (JRB, 14 years of experience; NF, 15 years of experience) who were blinded to all clinical information.

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Fig. 2. Coronal noncontrast-enhanced CT image demonstrating the measurement of the phi angle, defined as the angle between the vertical line drawn through the spine and the line drawn through the long axis of the band on a coronal view.

Fig. 3. Coronal contrasted enhanced CT scan with enteric contrast demonstrating a radio-opaque gastric band (denoted by the yellow arrow) illustrating the *en face* the "O" sign with the gastric band in a round or oval shape on coronal view.

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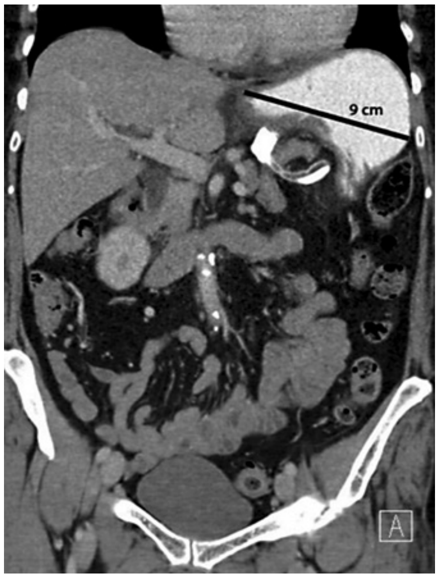

Fig. 4. Coronal contrast-enhanced CT with enteric contrast demonstrating 3.1 cm of inferior displacement of the gastric band, measured from the closest outer margin of the band to the esophageal hiatus on coronal view.

Fig. 5. Coronal contrast-enhanced CT with enteric contrast showing an enlarged gastric pouch proximal to the slipped gastric band.

CT Acquisition

Protocol for abdominal and pelvic CT was as follows: axial helical mode CT images were obtained from the lower chest through the pelvis using 120 kVp, automated tube current modulation (reference mA 200), minimum tube current 100–150 mAs, beam pitch 0.8–1.375, reconstructed section thickness and interval 2–5 mm. Patients who needing intravenous contrast received 120 mL (Isovue 300, 300 mg L/mL) injected at a rate of 3 mL/s, with imaging during portal venous phase. Some patients also received oral contrast, depending on the indication for the CT. Most of those needing oral contrast received dilute oral Omnipaque (positive) or water (neutral) approximately 30–60 min prior to the CT scan. Coronal and sagittal reformatted images were reconstructed from 0.625-mm thick axial sections.

Image Analysis and Data Acquisition

The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the phi angle, the "O" sign, band distance from the esophageal hiatus, and size of gastric pouch above the band were then analyzed for each reader. The following definitions were used in measuring each variable:

1. Phi angle: defined as the angle between the vertical line drawn through the spine and the line drawn through the long axis of the band on coronal CT images (Fig. 2). 20–60° was defined as normal based on previous reports using radiography [9].
2. CT "O" sign: the positive "O" sign was defined subjectively as the *en face* round or oval shape of the gastric band on coronal CT images (Fig. 3).
3. Inferior band displacement from the esophageal hiatus: defined as the distance from the esophageal hiatus to the closest outer margin of the band on coronal images (Fig. 4).
4. Gastric pouch size: defined as measurement of the gastric pouch size in all dimensions above the band on axial, coronal, and sagittal images (Fig. 5). The volume of the gastric pouch was calculated from these measurements.

Statistical Analysis

Regression analyses and univariate statistics were conducted in XLSTAT (Addinsoft 2020 XLSTAT statistical and data analysis solution, New York, NY, USA). Normality of variables was assessed using the Shapiro-Wilk method followed by the appropriate parametric/nonparametric statistics. Interobserver agreement

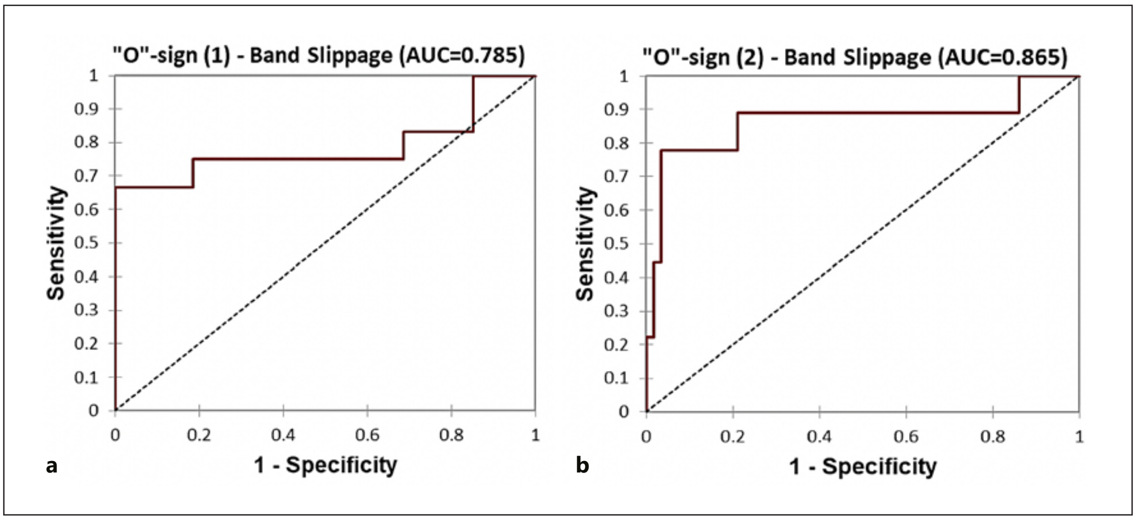

Fig. 6. ROC curves of the O-sign prediction of band-slippage from observers 1 (**a**) and 2 (**b**), respectively, by use of simple logistic regression.

Table 1. Summary statistics for each parameter measured

	"O"-sign	Phi-angle φ <20°, φ >60°	Displacement from hiatus >3.5 cm	Gastric pouch >55 cm^3
Sensitivity	0.667	**0.889**	0.667	0.727
Specificity	**1**	0.860	**1**	**1**
PPV	**1**	0.500	**1**	**1**
NPV	0.931	**0.980**	0.931	0.946
Model R^2	0.392	0.392	0.564	**0.782**
AUC	0.823	0.823	0.736	**0.991**
ICC	Cohen's kappa = 0.93	ICC = 0.97	N/A	**N/A**

The best parameters are bolded. ICC, intraclass correlation coefficient.

was assessed using Cohen's Kappa for categorical variables and intraclass correlation coefficient and spearman's rho for continuous variables. Data visualization was performed in R using the ggpubR package.

Results

Overall, there was good interobserver agreement between the two interpreting radiologists for gastric band slippage with a Cohen's kappa value of 0.83 based upon a 95% confidence interval. Table 1 summarizes the findings for each parameter.

The "O" sign parameter was 67% sensitive and 100% specific for gastric band slippage with corresponding PPV and NPV of 100% and 93%, respectively. This predictive parameter, when present on CT, demonstrated an area under the curve of 0.82. There was an excellent interobserver agreement between the two interpreting radiologists for the "O" sign evaluation with a Cohen's kappa value of 0.93 based upon a 95% confidence interval. Simple logistic regression demonstrated an AUC of 0.78 and 0.87 for the first and second readers, respectively (Fig. 6).

A phi angle <20° or >60° was found to be 89% sensitive and 86% specific with PPV and NPV of 50% and 98%, respectively. When identified on preoperative CT scan, abnormal phi angle predicted gastric band slippage with an area under the curve of 0.82. The two observer's readings were highly correlated (Spearman's rho = 0.91) and there was excellent intraclass correlation between the two interpreting radiologists (two-tailed intraclass correlation coefficient = 0.976 [95% CI = 0.960–0.985]) (Fig. 7).

Inferior gastric band displacement from the hiatus greater than 3.5 cm was 67% sensitive and 100% specific with PPV and NPV of 100% and 93%, respectively. This parameter predicted gastric band slippage with an area under the curve of 0.74.

A logistic regression correlated a pouch size of 55 cm^3 with a probability of gastric band slippage in the 95th per-

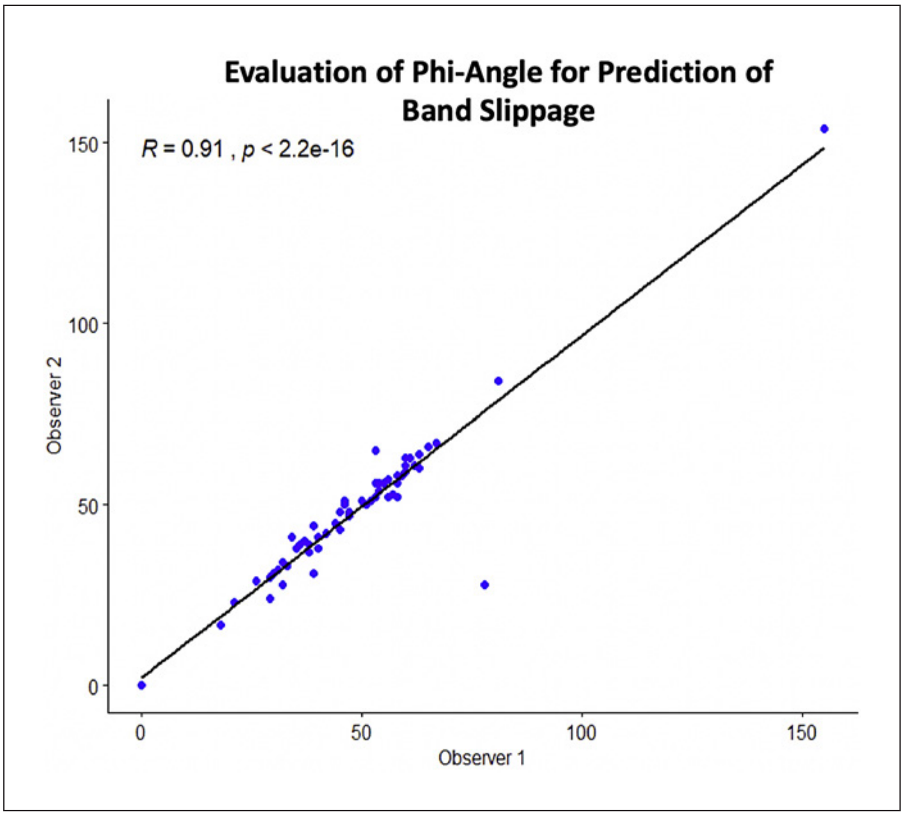

Fig. 7. Evaluation of interobserver agreement for phi-angle by Spearman's rank correlation. Spearman's rho = 0.91, $p < 2.2e^{-16}$. Two-tailed intraclass correlation coefficient (ICC) = 0.976 (95% CI = 0.960–0.985).

centile. Gastric pouch volume of >55 cm^3 was 73% sensitive and 100% specific when identified on CT. There was a 100% PPV and a 95% NPV with an excellent area under the curve of 0.99 (Fig. 8).

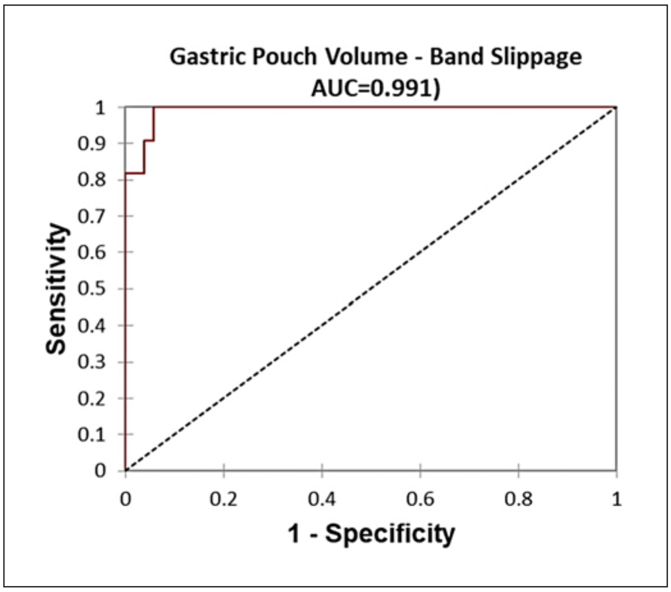

Fig. 8. ROC curve for band slippage as predicted by gastric pouch size (cm^3) using simple logistic regression. McFadden R^2 = 0.782, p = 0.012 (OR 1.194 95% CI: 1.039–1.371).

Discussion

The purpose of this study was to develop and validate reliable CT imaging criteria for the diagnosis of gastric band slippage. This study found that CT imaging findings of the "O" sign, inferior displacement from the hiatus greater than 3.5 cm, and a gastric pouch volume and size greater than 55 cm^3 to be 100% specific for detection of gastric band slippage based on CT. The phi angle was demonstrated to have the highest sensitivity (89%) as well as the highest NPV (98%) to aid in ruling out gastric band slippage.

The addition of preoperative abdominal CT in the clinical work-up of patients with suspected gastric band slippage has many advantages [10, 11]. CT scans are much faster and easier to perform than upper GI series, both for the patient and the radiologist. Newer CT scanners and postprocessing methods have the ability to scan patients at a much lower radiation dose than an upper GI series [12]. Abdominal CT is better at identifying complications other than band slippage, including gastric leak, abscess, obstruction, etc.

Expected gastric band positioning is in the paraspinal region of the left upper quadrant, located approximately 3–4 cm below the diaphragm with oblique orientation and superimposition of the anterior and posterior sides [9, 14, 15]. Additionally, the gastric pouch should be 3–4 cm in maximal dimension and symmetric in shape [15, 16]. In the setting of gastric band slippage, the stomach herniates cephalad to the band with subsequent caudal migration and changes in band angulation [15, 17, 18]. This expected imaging appearance led to the establishment of reliable fluoroscopic and radiographic based imaging predictors of the "O" sign, phi angle, inferior band displacement from the hiatus, and gastric pouch size, with the "O" sign and phi angle reported as most reliable in the radiology literature [9, 14, 15]. However, there is little previous literature regarding the accuracy of any of these predictors in slippage detection based on CT imaging.

Gastric band orientation is also directly affected by gastric pouch size and orientation. As the gastric pouch enlarges it herniates superiorly above the band and the increased volume and weight of the pouch causes a rotation of the band along its horizontal or oblique axis causing the anterior and posterior sides of the band to be viewed *en face* on coronal imaging [14, 19]. The abnormal gastric band orientation was designated as the "O" sign by Peironi et al. [14] who first documented this as a radiographic finding in 2010. Our study found that when identified on coronal CT, it was 100% specific and thus a reliable positive predictor of band slippage (AUC = 0.82) on CT.

In 2014, Swenson et al. [9] reported the presence of an air-fluid level above the gastric band on frontal radiograph to be 95% sensitive and 100% specific for gastric band slippage. Our study evaluated the analogous findings of enlargement of the gastric pouch about the band measuring >55 cm^3 in volume which was found to be 73% sensitive and 100% specific with an area under the curve of 0.99. Additionally, with an enlarged gastric pouch, there is increased reliable detection of the "O" sign and increased inferior displacement of the band from the esophageal hiatus.

A slipped gastric band becomes more horizontal in position with a phi angle greater than the normal 58° on radiograph [19]. In our study, we defined a normal phi angle on coronal CT as 20–60°, and measurements outside of this range had an 89% sensitivity and 86% specificity of band slippage. Of the identified imaging findings indicative of gastric band slippage, it demonstrated the highest NPV at 98% compared to 93%–94% for the other parameters, suggesting if a normal measurement is obtained on coronal CT, a radiologist can reliably exclude gastric band slippage as a cause for abdominal pain in a bariatric patient.

Limitations

This study is limited by its retrospective nature, thus increasing the potential for both selection and interpretation bias. These aforementioned biases were limited by performing a blinded imaging case interpretation by two independent radiologists. CT involves increased radiation in comparison with abdominal x-rays; however, due to the relatively poor sensitivity of abdominal x-rays and upper GI fluoroscopy for evaluating abdominal pain, in many circumstances, CT is the clinical standard to evaluate patients with abdominal pain after gastric band placement [12, 19]. Finally, our data are limited by use of a single institution with a small study group sample size who underwent surgical reintervention for band slippage.

Conclusions

The phi angle, "O" sign, gastric pouch size, and gastric band distance from the esophageal hiatus are all sensitive and specific CT imaging markers for the diagnosis of gastric band slippage. However, gastric pouch sizes followed by the presence of the "O" sign were found to be the most specific diagnostic parameters. Additionally, while not as specific as the other imaging findings, phi angle measurements have a high NPV and a normal measurement can be used by interpreting radiologists to exclude gastric band slippage in the absence of the other marker. Ultimately, identification of these imaging findings on CT will aid in rapid and appropriate patient triage with timely management of sequelae and potential surgical re-intervention, leading to improved patient care.

Statement of Ethics

This study was approved by the Orlando AdventHealth hospital institutional review board, approval #695961. The need for informed patient consent was waived by the Orlando AdventHealth Office of Sponsored Projects because of the retrospective nature of the study. We utilized the "safe harbor" method to deidentify patient data. All studies and imaging analysis were performed in compliance with HIPAA regulations.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Guarantor of integrity of the entire study – Jeremy Burt. Study concepts and design – Jeremy Burt and Nicholas Feranec. Literature research – Madison Kocher, Lauren Snider, Jeffrey Waltz, and Jeremy Burt. Clinical studies – Jeremy Burt and Nicholas Feranec. Experimental studies/data analysis – Madison Kocher, Lauren

Snider, Jeffrey Waltz, Jordan Chamberlin, Jeremy Burt, and Nicholas Feranec. Statistical analysis – Jordan Chamberlin and Jeremy Burt. Manuscript preparation – Madison Kocher, Lauren Snider, Jeffrey Waltz, Jordan Chamberlin, Megan Mercer, and Jeremy Burt. Manuscript editing – Megan Mercer, and Jeremy Burt.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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