



Clinical, radiographic, and intraoperative risk factors for retinal detachment after open globe injury

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Abstract

Purpose Retinal detachment (RD) is a vision-threatening complication of open globe injuries (OGI). This study sought to assess clinical, radiographic, and intraoperative risk factors for RD after OGI. A secondary goal was to test the retinal detachment after open globe injury (RD-OGI) score.

Methods Records of patients undergoing OGI repair at a single trauma center over 3 years were reviewed using a retrospective case series design. Eyes that were enucleated or lost to follow up within 30 days of OGI without evidence of RD were excluded. Potential risk factors for RD development were assessed by logistic regression or chi-square tests were appropriate and were entered into a multivariate logistic regression if significant on univariate analysis. Risk of RD for each eye was categorized by its RD-OGI score.

Results Seventy-three eyes (72 patients) were included. In univariate analysis, afferent pupillary defect, worse visual acuity, posterior injury, vitreous hemorrhage, and posterior segment volume loss (PSVL) on CT were strong predictors of RD. In multivariate analysis, only PSVL on CT (adjusted OR 10.8, $P = 0.025$) maintained a statistically significant association with RD risk. At 1 year, 5% of low-risk eyes, 20% of moderate-risk eyes, and 67% of high-risk eyes developed RD. These rates were not significantly different from the RD-OGI derivation or validation cohorts ($P = 0.90$ and $P = 0.67$, respectively).

Conclusion PSVL on CT increases the risk of RD after OGI. The RD-OGI Score was a good prognostic tool for assessing RD risk after OGI in this population.

Keywords Open globe · Traumatic retinal detachment · Orbital CT

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Introduction

Retinal detachment (RD) is a potentially blinding complication of open globe injury (OGI). With more than 200,000 OGIs occurring worldwide each year, reliable data on the risk of RD following OGI are helpful for prognostic purposes [1]. Despite the seriousness of retinal detachment, surprisingly little work has been done to identify specific risk factors for

RD after OGI. Standardized classification of OGI was first established in 1997 by the Ocular Trauma Classification Group [2]. In 2002, the Ocular Trauma Score (OTS) was established, providing a predictive scoring system for visual prognosis after OGI. The clinical factors upon which the score is based include initial visual acuity (VA) and the presence or absence of globe rupture, endophthalmitis, perforating injury, afferent pupillary defect (APD), and, notably, retinal detachment. Worse visual acuity and the presence of any of the aforementioned features result in poorer 6-month visual prognosis [3]. One study of 52 eyes that underwent OGI repair identified prior cataract removal, VA less than hand motions, and the presence of an intraocular foreign body as risk factors associated with significantly higher rates of RD after OGI [4]. Another similar study of 55 eyes identified posterior injury, APD, vitreous hemorrhage (VH), and hyphema as risk factors specifically for RD after OGI [5]. Recently, the retinal detachment after open globe injury (RD-OGI) score was established, providing a predictive tool for identifying eyes at risk of RD up to 1 year after presentation of OGI [6, 7]. Part of its appeal lies in the simplicity of the variables involved: presenting VA, zone of injury, and the presence of VH. Worse visual acuity, higher zone of injury, and the presence of VH at the time of presentation after OGI were all associated with significantly higher rates of RD on multivariate analysis. RD-OGI Scoring is described in Table 1, and eyes that have experienced OGI are defined as low (0–2), moderate (2.5–4.5), or high-risk (5–7.5) for RD. This score was initially established with a large cohort (893 eyes) from a

single tertiary care center and was later validated with an additional 66 eyes from the same institution between 2012 and 2014 [6, 7].

The primary goal of this study was to evaluate a range of risk factors for future RD at presentation of OGI, including radiographic as well as clinical variables. A second goal was to test the predictive value of the RD-OGI score in an external population and compare the results to the original derivation and validation cohorts.

Methods

This was a retrospective case series conducted at a single academic, level-one trauma center. The study was conducted in accordance with the Declaration of Helsinki and the Health Insurance Portability and Accountability Act (HIPAA) and was approved by the institutional review board (IRB) of the University of Louisville. An informed consent waiver was approved by the IRB in accordance with United States Code of Federal Regulations 45 CFR 46.116 (d).

Data collection

Electronic medical records of patients presenting with OGI between January 1, 2016, and January 1, 2019, were reviewed. Patients were followed from date of injury until the date of most recent follow-up. Inclusion criteria included clinical diagnosis of a ruptured globe with a diagnosis of RD at any time following OGI or with a minimum follow-up of at least 30 days after OGI if no RD was present. Eyes that underwent enucleation within 30 days or lacked follow-up of at least 30 days were excluded if they were not already diagnosed with retinal detachment after OGI. Clinical, demographic, and radiographic data were collected, including age, sex, date of injury, affected eye, presenting VA, zone of injury, presence of VH, afferent pupillary defect status, presence of uveal prolapse, presence of lens trauma, orbit computed tomography (CT) findings, presence of intraocular foreign body, date of RD, anterior vitrectomy at the time of OGI, ocular surgeries post OGI (including pars plana vitrectomy (PPV), and date of last follow-up. Vitreous loss was not routinely reported, and thus, that variable was not collected. This was also the case with mechanisms of injury (i.e., globe laceration

Table 1 RD-OGI scoring system [6]

Clinical finding at presentation	RD-OGI score points
VA > Counting fingers	0
Counting fingers	1
Hand motion	2
Light perception	2.5
No light perception	3.5
Zone I injury*	0
Zone II injury*	0.5
Zone III injury*	2
Vitreous hemorrhage	2

*Only the highest zone is scored

versus blunt rupture). In cases of uveal prolapse, intraoperative management, namely repositing of tissue versus excision with or without repositing, was also collected. CT findings were grouped into intact globe, shallow anterior chamber (AC), posterior segment volume loss (PSVL), and intraocular foreign body. PSVL was defined as a distortion of the normal circular shape of the sclera on CT or decrease in the expected size of the vitreous cavity compared to the fellow eye (Figs. 1 and 2). Zones of injury were consistent with the RD-OGI score derivation cohort's standards: Zone I injury is isolated to the cornea (including the limbus), zone II injury involves the sclera no more than 5 mm posterior to the limbus, and zone III injury involves the sclera more than 5 mm posterior to the limbus.

Statistical analysis

Data analysis was completed using the statistical software, R (The R Foundation, Vienna, Austria). Chi-

squared or Fischer's exact test were used to evaluate the correlation between categorical variables and RD, and univariate logistic regression for continuous variables. Variables that were correlated with RD (with statistical significance at the $P = 0.05$ level) were entered into a multivariable logistic regression model. Visual acuities were converted to logMAR values [8].

An RD-OGI score was computed for each eye. Eyes were assigned to low-risk (0–2), moderate-risk (2.5–4.5), or high-risk (5–7.5) categories. Rates of RD within each risk category were compared between this cohort and the RD-OGI score derivation and validation cohorts using Chi-square analysis.

Results

Eighty-two patients (83 eyes) treated for OGI within the established time frame were initially identified. Five patients were excluded due to enucleation within



Fig. 1 CT Orbits demonstrating significant posterior segment volume loss (PSVL) OS

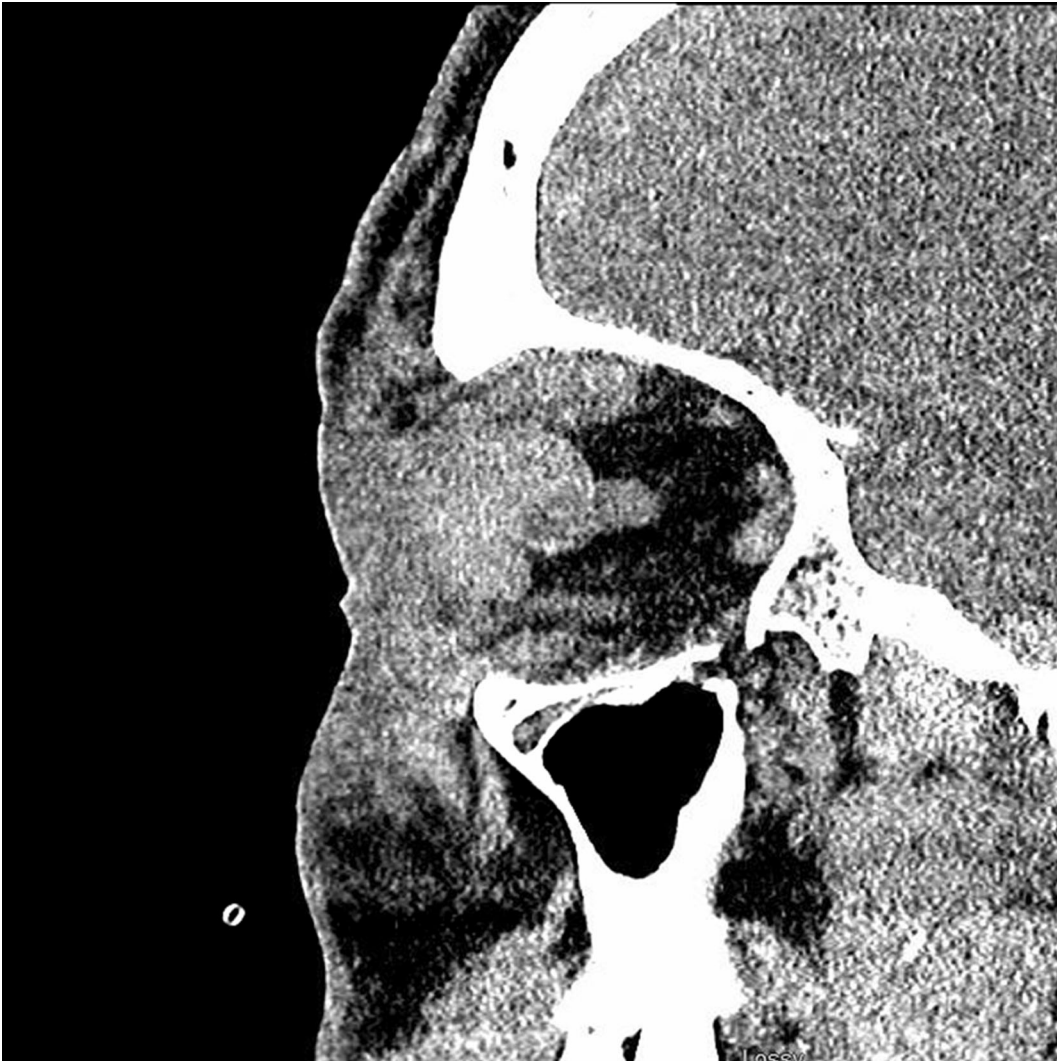


Fig. 2 Sagittal CT head demonstrating posterior segment volume loss (PSVL) OD

30 days of injury, and five were excluded with less than 30 days of follow-up time after injury. There were 50 males and 23 females with a median age of 37 years (range 2–88 years; interquartile range [IQR] 20–51 years). Twenty-six eyes (36%) developed RD (Table 2).

In univariate analysis, afferent pupillary defect (unadjusted odds ratio [OR] 9.25; 95% confidence interval [95%CI] 2.68–33.32; $P < 0.0001$), worse visual acuity ($P = 0.003$), higher zone of injury (Zone II vs. Zone I: OR 15.6; 95%CI 1.34–763.6; $P = 0.0047$) (Zone III vs. Zone I: OR 38.4; 95%CI 4.77–1640.1; $P < 0.0001$), presence of vitreous hemorrhage (OR 12.0; 95%CI 2.41–113.6; $P = 0.00031$),

and PSVL versus intact globe on CT radiographs (OR 8.18; 95%CI 2.28–31.1; $P < 0.0001$) were associated with increased RD risk (Table 3). Intraocular foreign body, PPV following OGI, and anterior vitrectomy during OGI were not associated with increased (or decreased) risk of RD. Indications for PPV following OGI included VH, IOFB, and scleral fixation of intraocular lens (IOL). Excision of uveal tissue after uveal prolapse was associated with higher risk of RD compared to cases without uveal prolapse (OR 7.65; 95%CI 1.32–47.9; $P = 0.012$) or cases in which the uvea was repositioned (OR 3.75; 95%CI 1.4–17.2; $P = 0.039$). Indications for uveal excision versus reposition were not routinely reported, but included

Table 2 Clinical characteristics of eyes that developed RD versus those that did not develop RD

Finding at presentation	Eyes that did not develop RD (%)	Eyes that developed RD (%)
Total number of eyes	47 (64)	26 (36)
Median age (IQR)	37 (17–48)	37.5 (25–56)
Male	32	18
Median presenting VA	Counting fingers	Light perception
VA \geq 20/40	8 (17)	–
\geq 20/80 and < 20/40	4 (9)	–
\geq 20/200 and < 20/80	2 (4)	–
\geq 20/800 and < 20/200	3 (6)	1 (4)
Counting fingers	3 (6)	–
Hand motion	12 (26)	5 (19)
Light perception	10 (21)	11 (42)
No light perception	3 (6)	9 (35)
Fixates and follows (pediatric)	1 (2)	–
VA not obtained	1 (2)	–
Afferent pupillary defect	8 (17)	18 (69)
APD missing	6 (13)	2 (8)
Vitreous hemorrhage	22 (47)	23 (88)
Zone I	25 (53)	1 (4)
Zone II	8 (17)	5 (19)
Zone III	12 (26)	20 (77)
Zone missing	1 (2)	–
Absence of uvea prolapse	10 (21)	2 (8)
Uvea excised	4 (9)	9 (35)
Uvea repositioned	24 (51)	10 (38)
Uvea prolapse, unspecified surgical technique	1 (2)	4 (15)
Uveal status not recorded	2 (4)	–
Pars Plana vitrectomy after OGI	6 (13)	2 (8)
Anterior vitrectomy after OGI	3 (6)	–
Lens trauma	24 (51)	14 (54)
Posterior segment volume loss on CT	5 (11)	10 (38)

suspected contamination or epithelialization of tissue and technical difficulty of repositioning tissue intraoperatively. There was no significant difference in RD risk between cases in which the uvea was repositioned and cases which had no uvea prolapse. On multivariate analysis, only PSVL on CT scan remained statistically significant (adjusted OR 10.8, $P = 0.025$).

Of the 73 eyes with OGI that were included, 69 had clinical data to support RD-OGI score calculation and risk category assignment. Scoring identified 19 low-risk eyes, 20 moderate-risk eyes, and 30 high-risk eyes. Within 1 year, 5% (1/19) of low-risk eyes, 20% (4/20) of moderate-risk eyes, and 67% (20/30) of high-risk eyes had developed RD, versus 3%, 29%, and

73% in the RD-OGI derivation cohort, respectively (Table 4) [3]. The validation cohort reported RD rates of 0% for low-risk, 35% for moderate-risk, and 86% for high-risk eyes [4]. Chi-squared analysis of observed RD rates in this cohort compared to expected RD rates (as predicted by the RD-OGI score derivation cohort) showed no significant difference ($P = 0.90$). The same analysis of observed RD rates in this cohort compared to those of the RD-OGI score validation cohort showed no significant difference between the moderate and high-risk categories ($P = 0.67$). Low-risk categories could not be compared between this cohort and the RD-OGI score validation cohort using Chi-square analysis, as the reported rate of RD in the

Table 3 Results of univariate analysis of individual clinical variables for correlation with RD

Clinical variable	Unadjusted OR (95% CI) for RD development	P value
Age		0.51
Sex (Male)	1.05 (0.34–3.46)	0.92
Visual acuity		0.046*
Afferent pupillary defect	9.25 (2.68–33.32)*	0.000086*
Vitreous hemorrhage	12.0 (2.41–113.6)*	0.00031*
Zone III versus I	38.4 (4.77–1640.1)*	0.000062*
Zone II versus I	15.6 (1.34–763.6)*	0.0047*
Zone III versus II	2.46 (0.55–11.64)	0.17
Uvea excised versus no uveal prolapse	7.65 (1.32–47.9)*	0.012*
Uvea repositioned versus no uveal prolapse	2.04 (0.50–10.0)	0.27
Uvea excised versus repositioned	3.75 (1.4–17.2)*	0.039*
Pars plana vitrectomy following OGI	0.70 (0.06–4.71)	0.68
Anterior vitrectomy following OGI	0 (0–2.71)	0.13
Lens trauma	2.38 (0.72–8.66)	0.12
PSVL versus intact globe	8.18 (2.28–31.1)*	0.00025*
Shallow AC versus intact globe	0 (0–30.1)	0.53
PSVL versus Shallow AC	0 (0–3.76)	0.09
Intraocular foreign body	0.77 (0.15–3.18)	0.69

*Denotes statistically significant findings

Table 4 Comparison of observed RD rates by risk category to the RD-OGI score derivation and validation cohorts

Risk category (RD-OGI score)	Observed RDs	Derivation cohort RD rate ⁶ %	Validation cohort RD rate ⁷ %
Low (0–2)	1/19 (5%)	3	0
Moderate (2.5–4.5)	4/20 (20%)	29	35
High (5–7.5)	20/30 (67%)	73	86

low-risk category was 0% in the validation cohort. Survival curves for each risk category are displayed in Fig. 3.

Discussion

This retrospective study of risk of retinal detachment after open globe injury found PSVL on CT scan to be an independent risk factor for retinal detachment. Afferent pupillary defect (APD), vitreous hemorrhage (VH), worse visual acuity (VA), excision of prolapsed uveal tissue, and higher zone of injury were predictive on univariate analysis but did not remain significant on

multivariate regression. The RD-OGI score derivation cohort, which included 893 eyes, determined that worse VA, presence of VH, and higher zone of injury were associated with higher rates of RD after multivariate analysis [6]. It is most likely that our study was insufficiently powered to conclude that these presenting clinical factors are significant predictors of RD after OGI, especially considering the fact that the RD-OGI score (which is determined by presenting VA, presence of VH, and zone of injury) was predictive of RD in this study's cohort as well as the derivation and validation cohorts without significant difference between the three. Previous clinical studies have noted strong associations between VH and RD risk

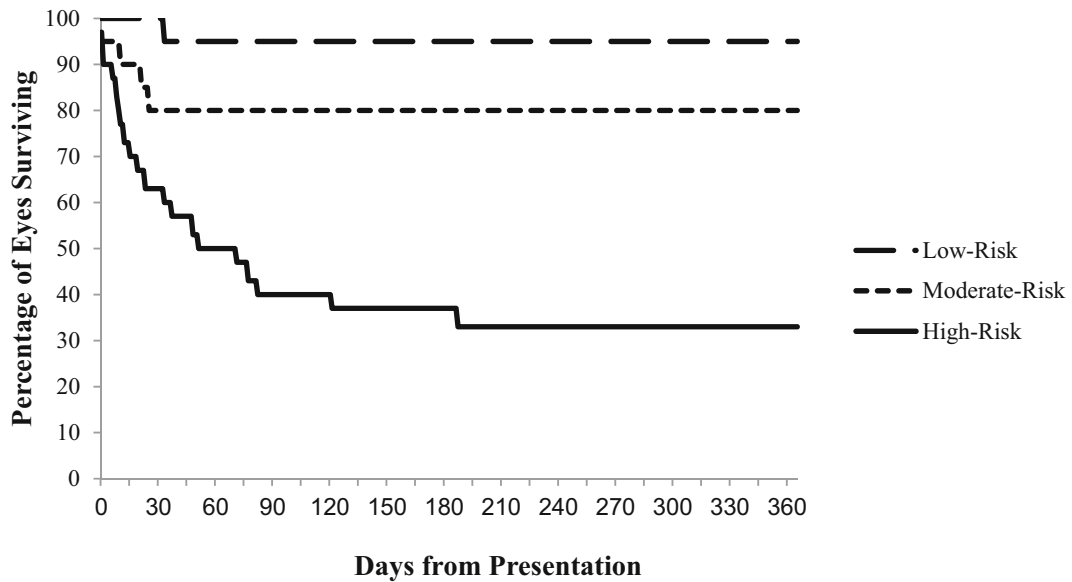


Fig. 3 Survival curves demonstrating percent of eyes remaining without RD for low (score 0–2), moderate (2.5–4.5), and high-risk (5–7.5) categories over time

after OGI, and animal models have also clearly established a causative role in the pathogenesis of retinal detachment after penetrating globe injuries [9–13]. Thus, the lack of association seen here appears spurious and perhaps stems from the limits of sample size or documentation in cases where VH may have been present but not appropriately noted at presentation or immediately post-operatively. Worse visual acuity on presentation is a well-established risk factor for RD after OGI and requires no further discussion [4, 6–8, 14, 15]. The presence of APD has been previously identified as a risk factor for RD after OGI [2]. Uveal excision may also prove to be predictive of RD after OGI on future analysis, though confounding variables may be a factor, such as early epithelialization due to duration of injury. One study reported the

presence of an intraocular foreign body (IOFB) as having a significantly increased risk of RD after OGI [4], but the RD-OGI score derivation study [6] and this cohort found no significant difference in RD rates between eyes with and without IOFB.

The finding of an increased risk of RD with PSVL on CT scan is intriguing. Although there have been several descriptions of orbital CT findings for open globe detection and their impact on visual outcomes, orbital CT findings have not previously been associated with increased RD risk after OGI. Orbital CT is the imaging modality of choice upon initial evaluation of suspected ruptured globe due to its wide availability, high resolution, rapid acquisition, and excellent safety in the setting of possible ferromagnetic foreign bodies [16]. A notable change in globe contour on CT

Table 5 Eyes with PSVL on CT scan by zone of injury and rate of RD

Zone of injury	Eyes with PSVL (% of total with PSVL, n = 15)	Eyes with PSVL and RD (% of total in the same zone of injury)
Zone I	3 (20%)	1 (33%)
Zone II	3 (20%)	2 (67%)
Zone III	8 (53%)	7 (88%)
Zone missing	1 (7%)	0
Any zone	15	10 (67%)

(which we have defined as evidence of PSVL) has been reported as predictive of OGI (specifically globe rupture) prior to surgical exploration, though not specifically for RD [17, 18]. The language used to describe the change in contour of the globe is not always consistent between radiologists, and it is sometimes described as scleral deformity or as a fractional decrease in globe volume [19, 20]. PSVL on CT implies a significant or even total loss of pressure in the eye. Since the vitreous cavity represents most of the volume of the eye, it is not surprising that a majority of globes with PSVL on CT are zone III injuries (Table 5), which create a direct communication between the vitreous cavity and the outside world and allow for significant vitreous loss. Interestingly, on multivariate analysis, zone III site of injury was *not* a statistically significant risk factor for RD, while PSVL was. One can infer that the latter finding conveys more information about the status of the eye after trauma than the former. Major volume loss likely indicates not only a posterior site of injury, and thus direct violation of the retina from trauma, but also more forceful trauma, greater vitreous loss, and thus greater vitreoretinal traction, which probably carry a greater risk of retinal tears or dialyses. To the best of our knowledge, this is a novel finding. While vitreous loss itself is likely the underlying pathophysiological mechanism for development of RD after OGI, PSVL noted on orbital CT may serve as a reasonable surrogate finding in cases where vitreous loss is not readily apparent during repair or is not reliably documented. More consistent language use among radiologists to describe this finding may be useful, but the observation of a change in the contour of the globe should be easily identified on review of the imaging by ophthalmologists.

Finally, our data support the RD-OGI score as a valid prediction model for RD after OGI. Comparison of RD rates between low, moderate, and high-risk categories between our cohort and the RD-OGI derivation and validation cohorts was not significantly different. The elegant simplicity and apparent validity of the RD-OGI score are notable strengths that make it a useful tool for clinicians.

Study limitations

This study's limitations largely arise from the inherent bias of retrospective studies. While most of these

clinical findings are standardized and largely objective, they are subject to some interrater variability. This caveat also applies to radiographic reports, as some radiologists may note PSVL where others may not. In general, this is a highly unsubtle finding, but some variability may exist in documentation. PSVL was not quantified, and the degree of vitreous loss could play a role in risk of RD development. Ultimately, vitreous loss is likely the true underlying pathophysiological mechanism for RD after OGI rather than the change in the contour of the globe noted on CT scan, and the presence or absence of vitreous loss was not consistently documented among patients within this cohort.

Potential confounding variables for which this study did not account include mechanism of OGI (blunt vs laceration vs. penetrating), indication for excising versus repositing uveal tissue, surgical techniques, time from injury or presentation to intervention, and underlying ocular disease/history (i.e., previous history of RD). Additionally, the study's power is limited by a sample size of 73 eyes. This study did not account for time to presentation after injury which could influence RD risk, although previous work has not found an increased RD risk when time from presentation (not time from injury to presentation) was compared to time of repair as starting points. Since most OGIs present within hours of injury, cases of delayed repair are uncommon, but this is an area of future consideration [5].

Author contributions All authors contributed to the study conception and design. Material preparation and initial data collection were performed by Travis Bales. Analysis was performed by Harpal S. Sandhu, MD. The first draft of the manuscript was written by Travis Bales with substantial contribution and revision by Harpal S. Sandhu, MD. Additional data collection and subsequent manuscript revision was performed by Tyler Ogden. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability De-identified patient data were contained in a single spreadsheet, which is available from any author upon reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Research ethics and patient consent In this retrospective study, care was taken to protect the identities of human subjects. Patient names were substituted with a numerical code. De-identified patient data were contained in a single spreadsheet. The study was approved by the University of Louisville Institutional Review Board (Study ID# 19.0068) and conducted in accordance with the Declaration of Helsinki and the Health Insurance Portability and Accountability Act (HIPAA). An informed consent waiver was approved by the IRB in accordance with United States Code of Federal Regulations [45 CFR 46.116 (d)].

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