Original research

BMJ Open Ophthalmology

Perioperative systemic blood pressure parameters and clinical outcomes following 27g vitrectomy for diabetic tractional detachment repair

Naveen R Ambati ,[1] Pavel Chernyavskiy,[2] Xiaoyu Cai,[1] Ryan T Duong,[1] Eugene Y Shildkrot[1]

To cite: Ambati NR, Chernyavskiy P, Cai X, *et al*. Perioperative systemic blood pressure parameters and clinical outcomes following 27g vitrectomy for diabetic tractional detachment repair. *BMJ Open Ophthalmology* 2023;**8**:e001130. doi:10.1136/bmjophth-2022-001130

Received 3 August 2022
Accepted 9 January 2023

[1]Department of Ophthalmology, University of Virginia School of Medicine, Charlottesville, Virginia, USA
[2]Department of Public Health Sciences, University of Virginia School of Medicine, Charlottesville, VA, USA

Correspondence to
Dr Eugene Y Shildkrot; shildkrot@gmail.com

ABSTRACT

Background Extremes in perioperative blood pressures are known risk factors for adverse outcomes after surgical interventions. There is scarce literature studying these parameters as predictors of outcomes after ocular surgery.
Methods This was a retrospective single-centre interventional cohort analysis to evaluate the relationship between perioperative (preoperative and intraoperative) blood pressure value and variability and postoperative visual and anatomic outcomes. Included were patients who underwent primary 27-gauge (27g) vitrectomy for repair of diabetic tractional retinal detachment (DM-TRD) with at least 6 months of follow-up. Univariate analyses were conducted via independent two-sided t-tests and Pearson's χ^2 tests. Multivariate analyses were conducted via generalised estimating equations.
Results 71 eyes of 57 patients were included in the study. Higher preprocedure mean arterial pressure (MAP) was associated with fewer Snellen lines of improvement at postoperative month 6 (POM6) (p<0.01). Higher mean intraoperative systolic blood pressure (SBP), diastolic blood pressure and MAP were associated with visual acuity 20/200 or worse at POM6 (p<0.05). Patients with sustained intraoperative hypertension had 1.77 times the risk of visual acuity 20/200 or worse at POM6 compared with those without sustained intraoperative hypertension (p=0.006). Higher SBP variability was associated with worse visual outcomes at POM6 (p<0.05). Blood pressure was not associated with macular detachment at POM6 (p>0.10).
Conclusions Higher average perioperative blood pressure and blood pressure variability are associated with worse visual outcomes in patients undergoing 27g vitrectomy for DM-TRD repair. Patients with sustained intraoperative hypertension were approximately twice as likely to have visual acuity 20/200 or worse at POM6 compared to those without sustained intraoperative hypertension.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Perioperative hypotension is a known risk factor for adverse outcomes after cardiac and non-cardiac surgery. There is no current consensus on the effect of perioperative hypertension on postoperative outcomes in non-ocular surgeries. Effects of blood pressure on eye-specific outcomes have not been well studied.

WHAT THIS STUDY ADDS

⇒ Higher perioperative blood pressures and blood pressure variability are associated with worse visual outcomes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This finding suggests that perioperative systemic hypertension may adversely impact visual outcomes and further evidence may aid in improving the guidelines for perioperative blood pressure management during vitreoretinal surgery in patients with high cardiovascular risk.

INTRODUCTION

Uncontrolled perioperative blood pressures are well-known risk factors for poor outcomes after cardiac and non-cardiac surgery. Numerous studies have demonstrated that intraoperative hypotension and higher blood pressure variability are associated with morbidity and mortality.[1–4] Effects of intraoperative hypertension are less clear, although authors have found association between unfavourable postoperative outcomes such as stroke and delirium.[5] While there is growing interest in optimising intraoperative blood pressure management to prevent end-organ damage, there is sparse and conflicting evidence on the association between blood pressure and surgical outcomes after ocular procedures. Agarwal *et al* did not find an association between preprocedure blood pressure and intraoperative complications during cataract surgery.[6] Mahalingam *et al* found preoperative blood pressure to be a risk factor for recurrent vitreous haemorrhage after vitrectomy while Ding *et al* and Motoda *et al* did not.[7–9] A potential source for the lack of consensus may stem from variability in cardiovascular risk profile within studied patient cohorts and short duration of the surgeries minimising the impact of intraoperative parameters on the outcomes.

To our knowledge, there are no published studies examining relationship between perioperative blood pressures or variability and outcomes following posterior segment ocular surgery. The purpose of this hypothesis-generating study was to evaluate postoperative outcomes in the light of perioperative (preoperative and intraoperative) blood pressures in patients with a high cardiovascular risk profile undergoing 27-gauge (27g) pars plana vitrectomy (PPV) for diabetic tractional retinal detachment (DM-TRD) repair.

METHODS AND MATERIALS

Patient cohort

This was a single-centre, retrospective interventional cohort study of patients who underwent 27g PPV by a single surgeon for DM-TRD from 2016 to 2020. It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research. Patients who underwent primary 27g PPV for DM-TRD repair with complete follow-up information of at least 6 months were included in the analytical sample.

Data collection

All data were collected through retrospective chart review. Severity of preoperative TRD was characterised and graded using preoperative OCT, B-Scan, documented exam findings and intraoperative findings (4—total retinal detachment, 3—macular detachment, 2—extramacular detachment only, 1—vitreoretinal traction only, 0—no vitreoretinal traction). Operative anaesthesia was classified as either monitored anaesthesia care (MAC) or general anaesthesia (GA). Fasting blood sugar and preprocedure blood pressure were collected on admission prior to the surgery. Only the highest preprocedure blood pressure was used for analysis. Intraoperatively, non-invasive systolic (SBP) and diastolic (DBP) blood pressures were collected and recorded every 5 min throughout the surgery. Mean arterial pressure (MAP) was calculated from each blood pressure reading using the formula MAP=(1/3*SBP)+(2/3*DBP). Mean and SD were calculated from all blood pressure recordings during surgery. SD was used as a measure of blood pressure variability. Intraoperative hypertension was defined as at least one SBP ≥180 mm Hg. Intraoperative hypotension was defined as at least one MAP≤65 mm Hg. Sustained blood pressures were defined as at least two consecutive blood pressure recordings of SBP ≥180 mm Hg or MAP ≤65 mm Hg. Postoperative visual acuity outcomes including change in logMAR from preoperative, presence of visual acuity 20/200 or worse, and number of Snellen lines of improvement from preoperative were collected at the postoperative month 6 (POM6) visit. Anatomic success was measured by the presence of macular attachment determined through ophthalmic imaging and fundus examination throughout the entire follow-up period. Lens opacities were graded preoperatively and at POM6 to track cataract progression. The presence of nuclear sclerosis (NS), posterior sclerosing cataract (PSC) and cortical cataract (CC) was graded on a scale from 0 to 4. For the purpose of this study, cataract progression was defined by any lens with a grade <2 in NS, PSC or CC that had a two-step grade increase in NS, PSC or CC by POM6.[10] Visually significant cataract was defined as ≥3+ NS, ≥3+ CC or any posterior subcapsular cataract.

Surgical technique

Anaesthesia choice between general versus monitored sedation was based on patient preference and medical status, with monitored anaesthesia care as the preferred option. Retrobulbar block with a 50:50 mixture of 4% lidocaine and 0.75% marcaine with hyaluronidase was administered for patients receiving MAC and peribulbar block was performed for those under GA. All patients underwent standard three-port vitrectomy using a 27g system. The Dutch Ophthalmic EVA vitrectomy system was used (Dutch Ophthalmic Research Center, Exeter, New Hampshire, USA). Core and peripheral vitrectomy was performed in all cases.

In select cases, extensive membrane dissection was carried out on shave mode using delamination and segmentation technique with the vitrector as a scissor in a ‘Pac Man’ approach. Forceps were used rarely in developing or elevating the edge of the membranes. The decision to perform retinotomy, often superonasally, was based on the presence of significant subretinal fluid causing macular folds during fluid-air exchange. If applicable, panretinal photocoagulation with endolaser was carried out for 360° and around retinal breaks. Filtered air or 20% sulfur hexafluoride (SF6) were used as tamponade agents in patients with no identified retinal breaks. For those with retinal defects, 14%–16% perfluoropropane (C3F8) was used. Silicone oil was reserved for complex retinal detachments that could not be flattened, in which case a single 23g cannula was placed. Sclerotomies were typically self-sealing but 7–0 Vicryl suture was used to close if the wound was not self-sealing or if silicone oil was used. Intraoperative bevacizumab injection was injected at the completion of all but one case due to availability.

Statistical analysis

Statistical analyses were performed examining correlation between adverse postoperative outcomes and preoperative and intraoperative blood pressures parameters including SBP, DBP, MAP and blood pressure variability assessed by SD of the above measures, after adjusting for confounding variables including age, sex, ethnicity, preoperative severity of detachment and the type of anaesthesia used. In a concurrent analysis for a different paper involving the same dataset, the authors found that preoperative A1c and history of amputation, end organ dysfunction, hypertension and major adverse cardiac/cerebral events were not associated with worse visual acuity or macular redetachment at POM6. As a result, these variables were not adjusted for in this analysis.

Independent two sided t-tests were performed to assess the relationships between type of anaesthesia and mean blood pressure, blood pressure variability and change in postoperative visual acuity from baseline as measured by logMAR. Pearson's χ^2 tests were performed to assess the relationships between type of anaesthesia, blood pressure outcomes (SBP ≥180 mm Hg, MAP ≤65 mm Hg) and visual outcomes (gain of three or more Snellen lines, visual acuity 20/200 or worse). 0.05 was selected as the significance level for each test.

Because outcomes were collected on each eye, which would be anticipated to be correlated (clustered) within patient, we estimated statistical models using generalised estimating equations (GEE). Visual acuity of 20/200 or worse and macular redetachment at POM6 were analysed using GEE for dichotomous outcomes. A number of

Snellen lines of improvement were coded and analysed using GEE for ordinal outcomes. Log-

MAR at month 6 was analysed using GEE for Normal outcomes. With the exception of

modelling macular redetachment, regression models included the risk factor of interest, categorical code for preoperative severity of detachment and categorical type of anaesthesia used. To avoid complete separation when modelling macular redetachment, we only adjusted those models for the type of anaesthesia used. The geepack R package V.1.3.3 was used for analysis. Estimated coefficients of each risk factor and the GEE-derived intrapatient correlations were calculated.[11 12] Continuous variables are reported as median (mean±SD, range). Visual outcomes are reported in logMAR as mean±SD (Snellen equivalent, range)

RESULTS

Demographics

Patient demographics are outlined in table 1. Seventy-one eyes of 57 patients met inclusion criteria. Of the 71 eyes, 39 (54.9%) were right eyes and 32 (45.1%) were left eyes. Median age at the time of surgery was 47 years (mean 45.77±11.82, range 28–69). Thirty (52.6%) patients were male and 27 (47.4%) were female. Systemic hypertension was the most common comorbidity, present in 46 (80.7%) patients. Median duration of diabetes was 20 years (mean 19.25±8.81, range 4 months–52 years). Median haemoglobin A1c was 8.85 (mean 9.02±2.20, range 5.0–14.6). Prior ophthalmic interventions included history of panretinal photocoagulation in 37 (64.9%) patients and history of anti-VEGF injections in 21 (47.4%) patients. Mean baseline logMAR visual acuity was 1.53±0.75 (20/678, range 0.18–2.7). Baseline characterisation of retinal detachment included total detachment in 11 (15.5%) eyes, macular-involving detachment in 23 (31%) eyes, extramacular detachment in 24 (33.8%) eyes and vitreoretinal traction in 14 (19.7%) eyes. Median

Table 1 Baseline patient demographics

No of patients	57
No of eyes	71
Laterality, # cases (%)	
Right	39 (54.9)
Left	32 (45.1)
Gender, # patients (%)	
Male	30 (52.6)
Female	27 (47.4)
Age in years: median (mean±D)	47 (45.77±11.8)
Ethnicity, # patients (%)	
White	28 (49.1)
African American	20 (35.1)
Asian	0 (0.0)
Hispanic	7 (12.3)
Other	2 (3.5)
Diabetes classification, # patients (%)	
Type 1	20 (35.1)
Type 2	37 (64.9)
Insulin-dependent diabetes	47 (82.5)
Diabetes severity parameters	
Preoperative A1C (%): median (mean±SD)	8.85 (9.02±2.20)
Duration of diabetes (years): median (mean±SD)	20 (19.25±8.81)
Duration of insulin use (years): median (mean±SD)	13 (14.73±11.60)
Medical comorbidities, # patients (%)	
Hypertension	46 (80.7)
Dialysis	2 (3.5)
Peripheral vascular disease	12 (21.1)
Major adverse cardiovascular event	13 (22.8)
Other end organ damage	27 (47.4)
History of ophthalmic interventions, # patients (%)	
Panretinal photocoagulation	37 (64.9)
Anti-VEGF injections	21 (47.4)
Baseline visual characteristics	
Preoperative logMAR (Snellen equivalent): median (mean±SD)	1.30 (20/400) (1.53 (20/678) ± 0.75 (20/112))
Baseline anatomic characteristics, # cases (%)	
Total detachment	11 (15.5)
Macular detachment	23 (31.0)
Extramacular detachment	24 (33.8)
Vitreoretinal traction only	14 (19.7)
Follow-up in months: median (mean±SD)	15 (16.99±9.64)

Table 2 Blood pressure characteristics

No of blood pressure recordings during surgery: median (mean±SD)	30 (32.73±16.47)
Preprocedure median MAP in mm Hg: median (mean±SD)	110.17 (109.1±15.2)
Intraoperative blood pressures values	
SBP in mm Hg: median (mean±SD)	137 (137.9±32.8)
DBP in mm Hg: median (mean±SD)	74 (73.4±15.2)
MAP in mm Hg: median (mean±SD)	96 (94.9±20.1)
SBP >180 mm Hg, # cases (%)	35 (49.3)
Sustained SBP >180 mm Hg, # cases (%)	22 (31.0)
MAP >120 mm Hg, # cases (%)	39 (55)
MAP <65 mm Hg, # cases (%)	14 (19.7)
Sustained MAP <65 mm Hg, # cases (%)	13 (18.3)
Use of vasopressors, # cases (%)	10 (14.1)
Use of antihypertensives, # cases (%)	11 (15.5)
Intraoperative variability (assessed by mean SD)	
SBP	14.64±7.09
DBP	7.71±3.48
MAP	9.53±4.62

DBP, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.

follow-up period was 15 months (mean 17.0±9.6, range 6–44). No patient mortality was observed in this cohort during the follow-up period.

Surgical details

Median case length was 97 min (mean 104.0±32.93, range 50–232). MAC was used in 53 (74.65%) patients and GA was utilised in 18 (25.35%) cases. No cases were aborted. Silicone oil was used in four (5.63%) cases. Perfluoro-N-octane was required in two (2.82%) cases. Intraoperative anti-VEGF injection was used in all (98.59%) but one case. The peripheral retina was successfully flattened at the end of all (98.59%) cases except one. Four (5.63%) patients required an additional 23g cannula for silicone oil tamponade. Sclerotomies were closed with sutures in seven (9.86%) cases, including all four cases involving silicone oil tamponade.

Perioperative blood pressure and anaesthesia type

Blood pressure data are summarised in table 2. A total of 2324 blood pressure recordings were collected for 71 cases. The median number of blood pressure recordings was 30 recordings (mean 32.73±16.47, range 7–92) and was determined by case duration. Median preoperative MAP decreased from 110.17 mm Hg (mean 109.1±15.2, range 77.3–146.7) to median intraoperative MAP of 96 mm Hg (mean 94.9±20.1, range 33.7–161.7) (p<0.001). Intraoperatively, median SBP was 137 mm Hg (mean 137.9±32.8, range 57–245) and median DBP was 74 mm Hg (mean 73.4±15.2, range 22–124).

Intraoperative SBP was ≥180 mm Hg at least once in 35 (49.3%) of cases. Of those cases, 22 (62.9%) had sustained intraoperative SBP ≥180 mm Hg. Intraoperative antihypertensive agents were administered in 11 (31.4%) of cases with at least one intraoperative SBP ≥180 mm Hg. There was no association between type of anaesthesia and intraoperative hypertension (SBP ≥180 mm Hg) (p=0.634).

Intraoperative MAP was ≤65 mm Hg at least once in 14 (19.7%) of cases. Of those cases, 13 (92.9%) had sustained intraoperative MAP ≤65 mm Hg. Intraoperative vasopressive medications were administered in 10 (71.4%) of cases with at least one intraoperative MAP ≤65 mm Hg. Mean intraoperative blood pressure (SBP, DBP and MAP) were more likely to be lower in patients undergoing GA compared with patients undergoing MAC (p<0.001). Patients who underwent GA had 10.80 times the risk of having intraoperative hypotension (MAP ≤65 mm Hg) compared with those who underwent MAC, with a prevalence of intraoperative hypotension of 11 (61.1%) in those who underwent GA compared with 3 (5.7%) in those who underwent MAC (p<0.001).

Mean variability of blood pressure measurements (SBP, DBP and MAP) was significantly greater in patients undergoing GA compared with patients undergoing MAC (p<0.003).

Visual and anatomic outcomes at POM6

At the POM6 visit, the macula was attached in 63 (88.73%) cases and retinal redetachment was observed in six (8.45%) eyes. Among eyes that were phakic at baseline, cataract progression by POM6 was noted in 10 (15.4%) of eyes and 4 (6.15%) eyes underwent cataract extraction and intraocular lens placement prior to POM6. All four cases that required silicone oil retained the oil at POM6. At POM6, 57 (80.3%) of all eyes had either a non-visually significant cataract or a PCIOL.

Visual acuity significantly improved from preoperative baseline mean logMAR of 1.53±0.75 (20/678, range 0.18–2.7) to POM6 of 1.20±0.91 (20/317, range 0–3) (p<0.001). The number of eyes with visual acuity 20/200 or worse decreased from 56 (78.87%) eyes preoperatively to 40 (56.34%) (p=0.004) at POM6 with 37 (52.11%) eyes demonstrating at least three Snellen lines of improvement at that time.

Risk factor analysis

POM6 visual and anatomic outcomes were analysed in the context of systemic blood pressure parameters including preoperative and intraoperative SBP, DBP, MAP values and measures of blood pressure fluctuation with estimated regression coefficients reported in table 3. Higher preprocedure MAP was associated with lower probability of improvement, as measured by Snellen lines (p<0.01). Higher mean intraoperative

Table 3 Regression analysis of blood pressure parameters and measures of blood pressure variability with clinical outcomes of 20/200 or worse vision, increase in Snellen lines of visual acuity, worsening logMAR vision and macular redetachment status at POM6, adjusted for preoperative level of detachment and type of anaesthesia used

Risk factor	Visual acuity of 20/200 or worse at POM6	Increased snellen lines of improvement at POM6	Worsening logMAR visual acuity at POM6	Macular redetachment at POM6
Higher preoperative MAP	0.013	−0.054**	0.010†	0.007
Higher mean intraoperative SBP	0.034*	−0.024†	0.011*	0.018
Higher mean intraoperative DBP	0.053*	−0.040	0.017	0.033
Higher mean intraoperative MAP	0.054*	−0.043†	0.018*	0.032
Higher intraoperative SD of SBP	0.100*	−0.083*	0.035*	−0.004
Higher intraoperative SD of DBP	0.126	−0.126	0.048	−0.109
Higher intraoperative SD of MAP	0.121†	−0.124*	0.046	−0.027

Notes: Risk factors are shown in rows and outcomes are shown in columns. The value of coefficients indicate a stronger association (for positive values) or reverse association (negative value) with the outcomes. The marker next to each coefficient indicates its statistical significance, and also conveys the uncertainty in the association relative to its strength. Coefficients with p<0.05 are highlighted with darker border and cell shading. The largest absolute value of the coefficients with the smallest p values, therefore, indicate the strongest and least noisy associations.
Coefficients were obtained using generalised estimating equations considering each patient as a cluster. All analyses were performed on 71 eyes (57 patients), except when using preoperative MAP where there were 68 eyes (55 patients).
*p<0.05, **p<0.01.
†p<0.10.
DBP, diastolic blood pressure; MAP, mean arterial pressure; POM6, postoperative month 6; SBP, systolic blood pressure.

SBP, DBP and MAP were each associated with increased probability of visual acuity 20/200 or worse at POM6 (p<0.05). Patients with intraoperative hypertension had 0.63 times the risk of having three or more Snellen lines of improvement compared with those without intraoperative hypertension, with a prevalence of three lines or more of improvement of 14 (40.0%) in those with intraoperative hypertension compared with 23 (63.9%) in those without intraoperative hypertension (p=0.044). Patients with sustained intraoperative hypertension had 1.77 times the risk of having visual acuity 20/200 or worse compared with those without sustained intraoperative hypertension, with a prevalence of visual acuity 20/200 or worse of 19 (79.1%) in those with sustained intraoperative hypertension compared with 21 (44.7%) in those without sustained intraoperative hypertension (p=0.006) as seen in table 4. Intraoperative hypotension was not associated with worse visual outcomes (p>0.082). The use of intraoperative antihypertensives and vasopressors was not associated with worse visual outcomes (p>0.150).

Higher variability of intraoperative SBP was associated with greater postoperative visual decline, increased probability of visual acuity of 20/200 or worse, and lower probability of improvement in≥3 Snellen lines as illustrated in figure 1A (p<0.05). Higher variability of intraoperative SBP was the strongest predictor of visual acuity 20/200 or worse with a GEE-based regression coefficient of 0.100 (table 3). Higher variability of intraoperative MAP was associated with decreased likelihood of improvement in ≥3 Snellen lines as illustrated in figure 1B (p<0.05). Higher variability of intraoperative MAP was the strongest predictor of fewer Snellen lines of improvement with a GEE-based regression coefficient of −0.124 (table 3).

There was no statistically significant association between blood pressure and macular attachment status at POM6 (p>0.10). There was no statistically significant association between perioperative fasting blood glucose and visual and anatomic outcomes. There was no statistically significant association between type of anaesthesia and visual outcomes (p>0.084).

DISCUSSION

To our knowledge, this is the first study to assess the relationship between perioperative blood pressure parameters and visual or anatomic outcomes in diabetic patients undergoing vitrectomy. In our study population of patients with retinal traction or detachment, median 20-year duration of diabetes, and 80% prevalence of known systemic hypertension who underwent retinal detachment repair with 27g vitrectomy, the retina was attached in approximately 90% of cases and visual acuity improved by at least 3 Snellen lines in over 50% of patients by POM6. Seventy-five per cent of the cases were performed under MAC. Intraoperative increase in SBP ≥180 mm Hg was noted in nearly 50% of the cases, while clinically significant MAP ≤65 mm Hg was observed at least once in 20% of cases with nearly all requiring intraoperative vasopressor medications. Poor visual outcome (20/200 or worse vision) was more likely in patients with higher intraoperative SBP, DBP and MAP. Notably, patients with sustained SBP ≥180 mm Hg were nearly twice as likely to have visual acuity 20/200 or worse at POM6 compared with patients who did not have

Table 4 Visual acuity outcomes in relation to various perioperative blood pressure parameters

			Visual acuity 20/200 or worse at POM6		3 snellen lines of improvement at POM6		Change in logMAR at POM6 from baseline	
		N (total)	n (%)	Significance (p value)	n (%*)	Significance (p value)	Mean±SD (Snellen)	Significance (p value)
SBP ≥180 mm Hg	y	35	23 (65.7)	0.116	14 (40.0)	0.044	−0.13±0.54 (20/27)	0.018
	n	36	17 (47.2)		23 (63.9)		−0.53±0.81 (20/68)	
Sustained SBP ≥180 mm Hg	y	22	19 (86.4)	0.006	9 (40.9)	0.205	−0.17±0.60 (20/30)	0.205
	n	49	21 (42.9)		28 (57.1)		−0.41±0.75 (20/51)	
MAP ≥120 mm Hg	y	35	26 (74.3)	0.003	17 (48.6)	0.556	−0.11±0.51 (20/26)	0.003
	n	36	14 (38.9)		20 (55.6)		−0.61±0.83 (20/81)	
MAP ≤65 mm Hg	y	14	5 (35.7)	0.82	5 (35.7)	0.170	−0.21±0.88 (20/32)	0.458
	n	57	35 (61.4)		32 (68.1)		−0.36±0.67 (20/46)	
Use of antihypertensives	y	12	8 (66.7)	0.429	7 (58.3)	0.636	−0.25±0.59 (20/36)	0.672
	n	59	32 (54.2)		30 (50.8)		−0.35±0.74 (20/45)	
Use of vasopressors	y	13	5 (38.5)	0.150	5 (38.5)	0.276	−0.13±0.88 (20/27)	0.263
	n	58	35 (60.3)		32 (55.2)		−0.38±0.67 (20/48)	

Notes: χ^2 p values reported for visual acuity 20/200 or worse and presence of three or greater Snellen lines of improvement. Independent t-test p value reported for change in logMAR at POM6 from baseline. Coefficients with p<0.05 are highlighted with darker border and cell shading.
*Per cent values reported as fraction of n out of N (total) for each parameter subgroup at POM6. Negative value of change in logMAR correlates with indicates improved vision.
MAP, mean arterial pressure; POM6, postoperative month 6; SBP, systolic blood pressure.

sustained SBP≥180 mm Hg. Patients with non-sustained SBP ≥180 mmHg were less likely to have three or more Snellen lines of improvement at POM6 than those without blood pressure elevation. Higher intraoperative variability in SBP was associated with worse measures of all visual outcomes studied.

The relationship between perioperative, and especially intraoperative, hypotension and poor surgical outcomes

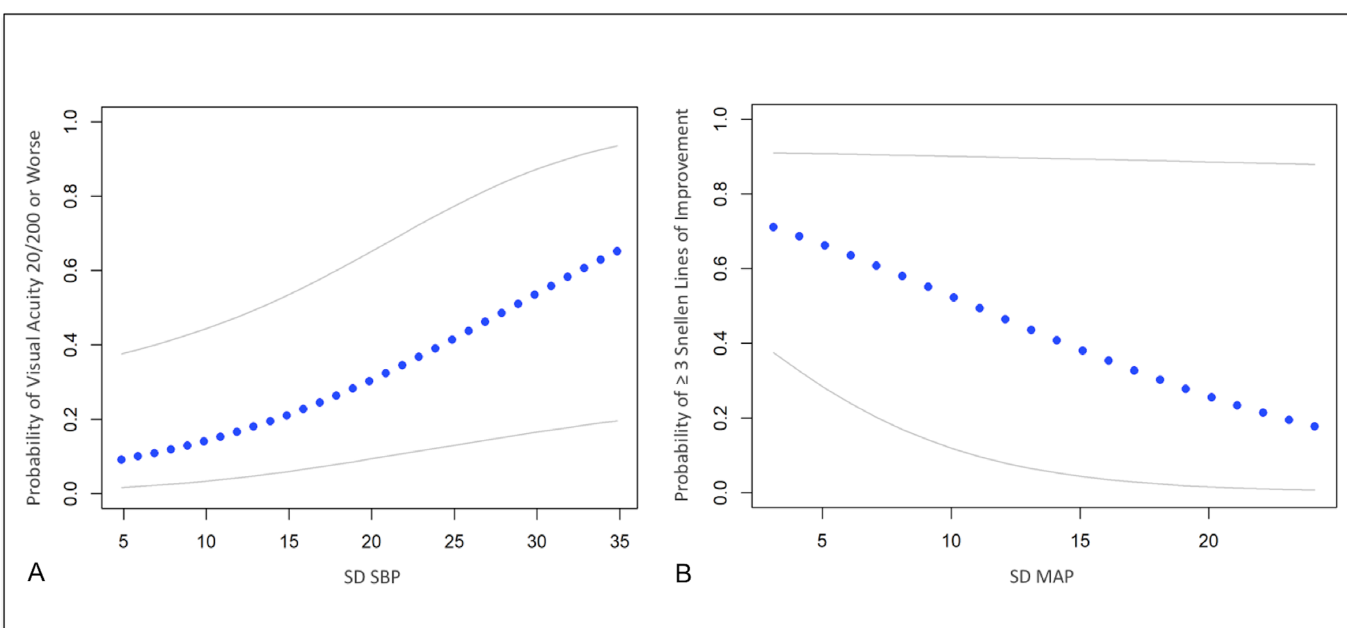

Figure 1 Estimated probabilities of (A) visual acuity 20/200 or worse at POM6 versus SD SBP (blue dots) and (B) at least three Snellen lines of improvement versus SD MAP (blue dots) with 95% CIs (grey lines). MAP, mean arterial pressure; POM6, postoperative month 6; SBP, systolic blood pressure.

after cardiac and non-cardiac surgery has been well studied. Ischaemia and reperfusion injury secondary to systemic hypotension is believed to cause acute kidney injury, myocardial infarction, delirium and other end-organ damage.[1–4] Despite this evidence, there are not guidelines establishing which blood pressure ranges constitute a hypotensive episode requiring intervention.[1] In our study focusing on functional outcomes of vision in patients with baseline ischaemic diabetic disease, worse outcomes were actually observed in patients with higher intraoperative blood pressures. With the majority of patients in this study not having GA, the observed rate of systemic hypotension (MAP≤65) was relatively rare at 20% and nearly every case was treated intraoperatively. This may explain lack of significant association between low MAP and visual outcomes in our cohort.

The impact of systemic perioperative hypertension on adverse surgical outcomes is less established for both cardiac and non-cardiac surgery. There are many proposed mechanisms of action including increased inflammatory responses, reperfusion injury and platelet activation which may contribute to microvascular injury.[13 14] However, the literature offers conflicting evidence as to whether intraoperative hypertension is a risk factor for poor surgical outcomes. Reich *et al* demonstrated that intraoperative hypertension was independently associated with adverse outcomes after major noncardiac surgery of long duration.[5] Basali *et al* demonstrated that patients with postcraniotomy intracranial haemorrhage were more likely to have been hypertensive during the surgery.[15] In contrast, Monk *et al* did not find intraoperative hypertension as a predictor for 30-day postoperative mortality following cardiac and non-cardiac surgery.[3] This study found that greater intraoperative blood pressure was associated with worse visual outcomes at POM6. Nearly 30% of patients had sustained SBP ≥180 mm Hg and almost 80% of these patients had visual acuity 20/200 or worse at POM6, nearly double of 44% rate in patients without sustained blood pressure elevation. Only a small portion of those received antihypertensive therapy. While this management is in line with guidelines aiming to avoid intraoperative hypotony, further research is needed to establish an optimal approach to minimising prolonged intraoperative hypertensive periods especially in patients undergoing MAC, considering their lower risk of intraoperative hypotension as seen in this study.

Recently, the relationship between intraoperative blood pressure variability and poor surgical outcomes after cardiac and non-cardiac surgery has garnered a lot of interest. There are numerous ways to quantify blood pressure variability, with notable limitations to each metric. The SD, as chosen in this study, is widely used and allows for ease of interpretation,[14] even though it does not incorporate variability between each subsequent measurement and is not robust to outliers.[16] High variability may indicate haemodynamic instability while low variability may indicate the inability to adapt to haemodynamic changes.[17] In a systematic review, Putowski *et al* found conflicting evidence that both high variability and low variability are associated with poor surgical outcomes.[17] This study found that higher SD of intraoperative SBP had association with all analysed markers of worse visual outcomes, while MAP variability was only associated with lower probability of improvement in Snellen lines. Measures of blood pressure variability were more predictive of poor postoperative visual outcomes than mean intraoperative SBP, DBP and MAP. The strength of association between blood pressure variability and postoperative visual outcomes emphasises the importance of tight blood pressure control especially in patients undergoing GA who are more likely to have increased blood pressure variability.

Within the field of ophthalmology, Agarwal *et al* found that preprocedure blood pressure was not associated with adverse events during phacoemulsification,[6] although cataract surgery is a much shorter procedure than the median tractional detachment repair duration of nearly 100 min seen in this study with lower requirement for anaesthetic medication use. Mahalingam *et al* found that high blood pressure was associated with delayed vitreous rebleed after vitrectomy while Ding *et al* and Matoda *et al* did not.[7–9] Further, Suguira *et al* found an association between ophthalmodynamometric pressure, which assesses blood perfusion of the eye, and diastolic blood pressure.[18]

The patients with diabetic tractional detachments are significantly sicker than other ophthalmology patients with high prevalence of comorbidities as seen in this study. Diabetic vascular disease is characterised by significant pathologic changes to the microcirculation of the retina and kidneys and the macrocirculation. These vasculopathic changes secondary to increased angiogenic factors (VEGF and Ang-2) and hyperglycaemia may predispose patients to poor blood pressure control.[19 20] The longer duration of tractional detachment repair, compared with other ophthalmological procedures, and resulting greater cumulative effects of intraoperative blood pressure parameters may have a more durable impact on patients' visual outcomes. A 27g vitrectomy offers the opportunity to decrease duration of surgery and improve pain control, which may allow more patients to avoid GA, which accounted for only 25% of cases in this study.[21] Lower anaesthetic requirement decreases the risk of intraoperative systemic hypotension in cases performed under MAC, which was seen in only 5.66% of cases who underwent MAC.[22]

There is conflicting evidence on the effect of fasting blood glucose on surgical outcomes after diabetic vitrectomy. Matoda *et al* and Mahalingam *et al* found an association between perioperative fasting blood glucose and vitreous haemorrhage but Ding *et al* did not.[7–9] We did not find that perioperative fasting blood glucose was a statistically significant predictor for adverse visual or anatomical outcomes.

Our study is limited by the retrospective nature and is hypothesis-generating as there are no clear guidelines for perioperative blood pressure management that are outcomes evidence-driven in patients undergoing tractional diabetic detachment repair. The severity of baseline retinal disease and presence of vitreous haemorrhage in this study limited the ability to ascertain the degree of foveal non-perfusion at baseline. It is often difficult to determine precise duration of tractional diabetic retinal detachment due to its slow progressive nature and it is not as strongly correlated to visual outcomes as the severity of the detachment. The focus of this study was not to evaluate all determinates of visual loss in this population, but to use visual loss as a functional end-organ endpoint in evaluating perioperative blood pressure management. To minimise the effect of confounding variables, statistical analyses accounted for intrapatient clustering and baseline variables, including severity of preoperative retinal detachment and type of anaesthesia. Given that the data included two eyes from same patients, the intrapatient correlations derived from the GEE model highlight the need to account for within patient clustering. There are no universally agreed on measure of blood pressure variability and better measures than SD may be needed.[16] In addition, recorded outcomes were limited to 6 months after surgery to focus on the short-term effects as use of long-term endpoints would confound the effect of perioperative variables by ongoing blood pressure control parameters in the outpatient setting. Even with this limitation, it is possible that the associations observed in this study may be reflective of or influenced by long-standing blood pressure effect on the vision with potential for greater blood pressure elevation and variability with surgical stress in patients with baseline poor blood pressure control.

We hope this study will highlight the effect of systemic hypertension on visual outcomes even in patients undergoing surgery under local anaesthesia with minimally invasive 27g PPV. Our findings may inform the design of future prospective studies incorporating more stringent blood pressure management, better data about blood pressure variables and control outside of the surgical setting, and individual data on the blood pressure response to intraoperative blood pressure control management.

CONCLUSION

This study is the first to examine and demonstrate an association between elevated intraoperative blood pressure and blood pressure variability and adverse visual outcomes in patients with diabetes undergoing TRD repair with 27g vitrectomy. Patients with sustained SBP ≥180 mm Hg were nearly twice as likely to have visual acuity 20/200 or worse at POM6. Stricter guidelines for intraoperative hypertension management control may improve visual outcomes in these patients with high cardiovascular risk profile.

Contributors NRA, XC and RTD were responsible for planning, dataset design, data collection, data synthesis and manuscript writing. PC was responsible for data analysis, manuscript writing and editing. EYS was responsible for planning, designing the project, providing oversight and manuscript editing and is acting a guarantor, accepting full responsibility for the work and/or conduct of the study, having had full access to the data, and controlled the decision to publish..

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study was approved by University of Virginia IRB. A HIPAA-complaint database was obtained to review medical records, store data, perform data analysis and publish findings. This research adhered to the tenets of the Declaration of Helsinki and was conducted in accordance with regulations set forth by the Health Insurance Portability and Accountability Act. This study involved human participants and was approved by the University of Virginia Ethics Committee #18646.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

ORCID iD

Naveen R Ambati http://orcid.org/0000-0001-6046-0197

REFERENCES

1 Sessler DI, Bloomstone JA, Aronson S, *et al*. Perioperative quality initiative consensus statement on intraoperative blood pressure, risk and outcomes for elective surgery. *Br J Anaesth* 2019;122:S0007-0912(19)30050-9:563–74:. 10.1016/j.bja.2019.01.013. Available: https://doi.org/10.1016/j.bja.2019.01.013

2 Meng L, Yu W, Wang T, *et al*. Blood pressure targets in perioperative care. *Hypertension* 2018;72:806–17. 10.1161/HYPERTENSIONAHA.118.11688. Available: https://doi.org/10.1161/HYPERTENSIONAHA.118.11688

3 Monk TG, Bronsert MR, Henderson WG, *et al*. Association between intraoperative hypotension and hypertension and 30-day postoperative mortality in noncardiac surgery. *Anesthesiology* 2015;123:307–19. 10.1097/ALN.0000000000000756. Available: https://doi.org/10.1097/ALN.0000000000000756

4 Walsh M, Devereaux PJ, Garg AX, *et al*. Relationship between intraoperative mean arterial pressure and clinical outcomes after noncardiac surgery: toward an empirical definition of hypotension. *Anesthesiology* 2013;119:507–15. 10.1097/ALN.0b013e3182a10e26. Available: https://doi.org/10.1097/ALN.0b013e3182a10e2

5 Reich DL, Bennett-Guerrero E, Bodian CA, *et al*. Intraoperative tachycardia and hypertension are independently associated with adverse outcome in noncardiac surgery of long duration. *Anesth Analg* 2002;95:273–7, 10.1097/00000539-200208000-00003. Available: https://doi.org/10.1097/00000539-200208000-00003

6 Agarwal PK, Mathew M, Virdi M. Is there an effect of perioperative blood pressure on intraoperative complications during phacoemulsification surgery under local anaesthesia? *Eye (Lond)* 2010;24:1186–92. 10.1038/eye.2010.4. Available: https://doi.org/10.1038/eye.2010.4

7 Mahalingam P, Topiwalla TT, Ganesan G. Vitreous rebleed following sutureless vitrectomy: incidence and risk factors. *Indian J Ophthalmol* 2018;66:558–61. 10.4103/ijo.IJO_770_17. Available: https://doi.org/10.4103/ijo.IJO_770_17

8 Ding Y, Yao B, Hang H, *et al*. Multiple factors in the prediction of risk of recurrent vitreous haemorrhage after sutureless vitrectomy for non-clearing vitreous haemorrhage in patients with diabetic retinopathy. *BMC Ophthalmol* 2020;20:292:292:. 10.1186/s12886-020-01532-8. Available: https://doi.org/10.1186/s12886-020-01532-8

9 Motoda S, Shiraki N, Ishihara T, *et al*. Predictors of postoperative bleeding after vitrectomy for vitreous hemorrhage in patients with

diabetic retinopathy. *J Diabetes Investig* 2018;9:940–5. 10.1111/jdi.12791. Available: https://doi.org/10.1111/jdi.12791
10 Srinivasan S, Raman R, Swaminathan G, *et al*. Incidence, progression, and risk factors for cataract in type 2 diabetes. *Invest Ophthalmol Vis Sci* 2017;58:5921–9. 10.1167/iovs.17-22264. Available: https://doi.org/10.1167/iovs.17-22264
11 Liang K-Y, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika* 1986;73:13–22.
12 Højsgaard S, Ulrich H, Jun Y. n.d. The R package geepack for generalized estimating equations. *J Stat Softw*2006:1–11.
13 Aronson S, Stafford-Smith M, Phillips-Bute B, *et al*. Intraoperative systolic blood pressure variability predicts 30-day mortality in aortocoronary bypass surgery patients. *Anesthesiology* 2010;113:305–12. 10.1097/ALN.0b013e3181e07ee9. Available: https://doi.org/10.1097/ALN.0b013e3181e07ee9
14 Benolken MM, Meduna AE, Klug MG, *et al*. Preoperative and intraoperative blood pressure variability independently correlate with outcomes. *J Surg Res* 2021;266:S0022-4804(21)00279-1:387–97: . 10.1016/j.jss.2021.04.027. Available: https://doi.org/10.1016/j.jss.2021.04.027
15 Basali A, Mascha EJ, Kalfas I, *et al*. Relation between perioperative hypertension and intracranial hemorrhage after craniotomy. *Anesthesiology* 2000;93:48–54. 10.1097/00000542-200007000-00012. Available: https://doi.org/10.1097/00000542-200007000-00012
16 Mascha EJ, Yang D, Weiss S, *et al*. Intraoperative mean arterial pressure variability and 30-day mortality in patients having noncardiac surgery. *Anesthesiology* 2015;123:79–91. 10.1097/ALN.0000000000000686. Available: https://doi.org/10.1097/ALN.0000000000000686
17 Putowski Z, Czok M, Krzych ŁJ. The impact of intraoperative blood pressure variability on the risk of postoperative adverse outcomes in non-cardiac surgery: a systematic review. *J Anesth* 2022;36:316–22. 10.1007/s00540-022-03035-w. Available: https://doi.org/10.1007/s00540-022-03035-w
18 Sugiura Y, Okamoto F, Okamoto Y, *et al*. Ophthalmodynamometric pressure in eyes with proliferative diabetic retinopathy measured during pars plana vitrectomy. *Am J Ophthalmol* 2011;151:624–629. 10.1016/j.ajo.2010.09.025. Available: https://doi.org/10.1016/j.ajo.2010.09.025
19 Strain WD, Paldánius PM. Diabetes, cardiovascular disease and the microcirculation. *Cardiovasc Diabetol* 2018;17:57. 10.1186/s12933-018-0703-2. Available: https://doi.org/10.1186/s12933-018-0703-2
20 Wang A, Abramowicz AE. Role of anesthesia in endovascular stroke therapy. *Curr Opin Anaesthesiol* 2017;30:563–9. 10.1097/ACO.0000000000000507. Available: https://doi.org/10.1097/ACO.0000000000000507
21 Li J, Liu S-M, Dong W-T, *et al*. Outcomes of transconjunctival sutureless 27-gauge vitrectomy for vitreoretinal diseases. *Int J Ophthalmol* 2018;11:408–15. 10.18240/ijo.2018.03.10. Available: https://doi.org/10.18240/ijo.2018.03.10
22 Zachariah JP, Xanthakis V, Larson MG, *et al*. Circulating vascular growth factors and central hemodynamic load in the community. *Hypertension* 2012;59:773–9. 10.1161/HYPERTENSIONAHA.111.179242. Available: https://doi.org/10.1161/HYPERTENSIONAHA.111.179242