Intraocular Pressure Changes During Cardiopulmonary Bypass Pump and Off-Pump Cardiac Surgeries

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Do intraocular pressure changes during cardiac surgery play a role in the development of anterior ischemic optic neuropathy?

The complication of anterior ischemic optic neuropathy (AION) occurs in up to 1.3% of patients undergoing cardiac surgery with cardiopulmonary bypass (CPB).[1] AION's effects can be devastating—some cases cause unilateral or bilateral blindness. And, unfortunately, no effective treatment for such vision loss is available.

The pathogenesis of AION, both in general and during CBP surgery, is most likely multifactoral, but has not been established with certainty. A crowded optic disc, marked hyperopia, diabetes mellitus, hypertension, and severe anemia are known predisposing factors for the development of AION. Ischemic optic neuropathy also has been reported after noncardiac surgeries, including aortobifemoral surgery, spine surgery, and abdominal exploration.[2–4] Severe anemia and hypotension were thought to be the most significant risk factors for postoperative vision loss in these reports.

With regard to CPB surgery, intraocular pressure (IOP) increase has been proposed as a factor in the pathogenesis of AION. Imbalance produced by lowering optic nerve perfusion pressure or increasing IOP during CPB might lead to optic nerve ischemia as a result of compromised blood flow.[5–7] But data on this issue is conflicting: Several studies have reported an increase in IOP during CPB surgeries,[5–7] while others have reported a decrease[8] or no change.[9] Hypothermia, hypotension, hemodilution with resulting anemia, microembolization, and CPB pump–related platelet dysfunction also may contribute to the development of AION after CPB.[1,2,10–14]

Comparisons between CPB cardiac surgeries and off–CPB pump, or off-pump (OP), cardiac surgeries could be useful in determining the role of IOP and other factors in the complication's pathogenesis. Although 10% to 15% of cardiac surgeries currently are performed with OP procedures, medical literature contains only two case reports of AION after such procedures.[15,16] In the first case, the patient's potential risk factors for AION included a small cup-to-disc ratio, as well as new onset of atrial fibrillation, hypotension, and severe anemia that developed two days postoperatively.[15] In the second case, the etiology of bilateral AION appeared to be a low hematocrit level on the third postoperative day.[16] OP surgery is associated with hemodynamic instability (especially during the interval of graft to coronary anastomosis), which can be caused by changes in the position of the patient or his or her heart during surgical exposure.[17] It is not known, however, if positional changes and their associated hemodynamic instability are accompanied by significant changes in IOP. Neither report of AION after OP cardiac surgery mentioned IOP measurements.[15,16]

To enhance understanding of AION's pathogenesis after CPB cardiac surgery, we undertook a prospective study that, to our knowledge, is the first to compare changes in IOP and other factors during CPB and OP cardiac surgeries. This article describes our results and discusses their possible implications.

METHODS

We performed a prospective, observational clinical study at the Edward Hines, Jr. VA Hospital (EHJVAH), Hines, IL that was approved by the

At the time of this study, **Dr. Park** and **Dr. Tidow-Kebritchi** were ophthalmology residents, **Dr. Bu** was a research specialist in the ophthalmology department, and **Dr. DePinto** was a staff physician in the cardiothoracic surgery section of the surgery service, all at Edward Hines, Jr. VA Hospital (EHJVAH), Hines, IL. In addition, Dr. Park and Dr. Tidow-Kebritchi were ophthalmology residents at Loyola University (LU), Chicago, IL. At present, Dr. Park is an ophthalmologist in private practice at Kovach Eye Institute in Naperville, IL; Dr. Tidow-Kebritchi is an assistant professor of ophthalmology at LU; Dr. Bu is a research associate in the department of ophthalmology at LU; and Dr. DePinto is the chief of the employee health section of the medicine service at EHJVAH. **Dr. Kleinman** is a physician in the anesthesiology section of the surgical service at EHJVAH and a professor of anesthesiology at LU. **Dr. Perlman** is the chief of the ophthalmology section of the surgical service at EHJVAH and an associate professor of ophthalmology and pathology at LU.

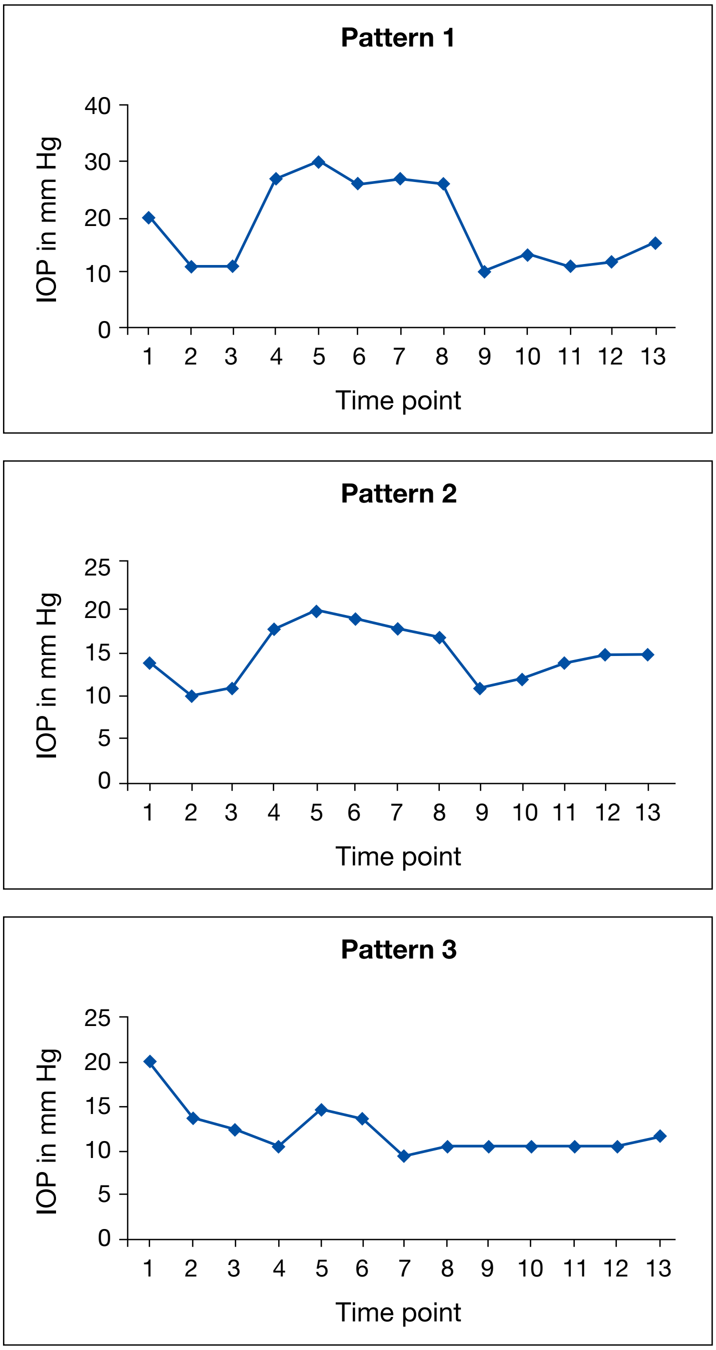

Figure 1. Patterns of variation in intraocular pressure (IOP) in patients who underwent cardiopulmonary bypass (CPB) cardiac surgery (n = 27). Time points are as follows: 1 = preintubation, 2 = postanesthetic, 3 = pre–CPB, 4 = immediately post-CPB, 5 = 5 minutes post-CPB, 6 = 10 minutes post-CPB, 7 = 15 minutes post-CPB, 8 = 30 minutes post-CPB, 9 = 60 minutes post-CPB, 10 = 120 minutes post-CPB, 11 = 180 minutes post-CPB, 12 = restart heart, 13 = stop CPB.

facility's Human Studies Institutional Review Board. Patients scheduled for CPB or OP cardiac surgery were recruited for the study several days prior to undergoing surgery. An informational letter describing the study's purpose and procedure was reviewed and discussed with each of these patients, and all enrollees signed informed consent forms.

For all of the study patients, IOP was measured with a handheld tonometer called the Tono-Pen XL (Medtronic Solan, Jacksonville, FL) at several points before and during surgery. In patients who underwent CPB surgery, IOP was measured before anesthesia; after induction of anesthesia; before CPB; at five, 10, 15, 30, 60, 120, and 180 minutes after the start of CPB; after the heart was restarted; and after CPB was stopped. In patients who underwent OP surgery, IOP was measured before anesthesia, after induction of anesthesia, before positioning, five minutes after positioning-stitching, after repositioning, and after reperfusion. For all patients, IOP was measured three times in each eye at each time point. In addition, blood pressure (BP), body temperature, partial pressure of carbon dioxide (pCO_2), pH, and hematocrit levels were measured in all patients during their surgeries.

All data analyses were carried out using S-Plus 2000 Release 1 (Insightful Corporation, Seattle, WA). Graphical displays of the data were produced to gain insight into the patterns of variation in IOP and to explore associations among variables. To simplify the analysis, the IOP was averaged separately for each eye, and the average IOP of the two eyes was used for all analyses of IOP. Changes in IOP were summarized by the mean and standard deviation using a 95% confidence interval. Statistical significance of changes in IOP over time were evaluated using the Wilcoxon signed rank test. Associations among continuous scaled variables were measured using the Spearman rho statistic.

RESULTS

A total of 34 patients were enrolled in the study. Of these patients, 27 (79%) underwent CPB surgery and seven (21%) underwent OP surgery. None of the patients reported any visual symptoms during the immediate postoperative period.

All patients showed a decrease in IOP after the induction of anesthesia—likely a factor of the induction agent. For patients who underwent CPB surgery, the mean (SD) IOP decrease was 4.8 (2.3) mm Hg. For patients who underwent OP surgery, the mean (SD) IOP decrease was 4.2 (3.3) mm Hg. The pattern of change in IOP was very similar in both eyes for all patients.

Among patients who underwent CPB surgery, a significant increase in IOP was evident within 15 minutes following initiation of CPB. The mean (SD) IOP increase was 4.7 (4.6) mm Hg, and the variation in IOP could largely be described by three patterns (Figure 1). Ten patients (37%) exhibited pattern 1, characterized by a preintubation IOP greater than 15 mm Hg, a large decrease in IOP from preintubation to postintubation, and a large increase in IOP from before CPB to after CPB. Seven patients (26%) exhibited pattern 2, characterized by a preintubation IOP of 15 mm Hg or less, a large decrease in IOP from preintubation to postintubation, and a large increase in IOP from before to after CPB. Four patients (15%) exhibited pattern 3, characterized by a preintubation IOP greater than 15 mm Hg, a large decrease in IOP from preintubation to postintubation, and a small increase in IOP from before to after CPB.

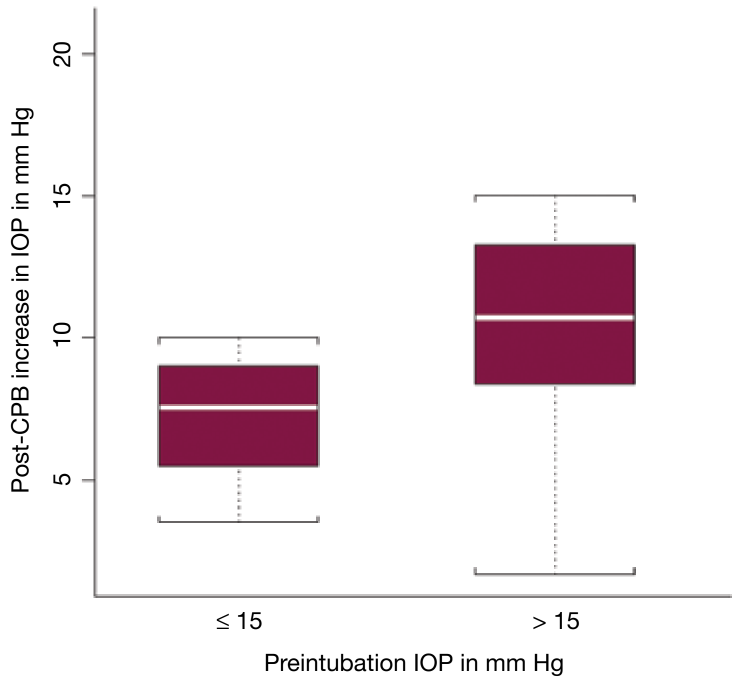

Figure 2. Amount of intraocular pressure (IOP) increase from preintubation to post–cardiopulmonary bypass (CPB) in 11 patients with a pre–CPB surgery intubation IOP of 15 mm Hg or less and 16 patients with a pre–CPB surgery intubation IOP of greater than 15 mm Hg. *P* = .014 according to the Wilcoxon Rank-sum test.

A preintubation IOP greater than 15 mm Hg was a statistically significant predictor of maximal IOP change—the difference between maximum value after CPB and minimum value before CPB—in patients who underwent CPB surgery (Figure 2). Sixteen (59%) of these patients had such an IOP value. The mean (SD) maximal IOP change in patients who underwent CPB surgery was 7 (2.1) mm Hg for patients with a preintubation IOP of 15 mm Hg or less versus 11.3 (4.8) mm Hg for patients with a preintubation IOP greater than 15 mm Hg ($P = .008$).

In patients who underwent OP surgery, no statistically significant IOP elevation above baseline was observed. In addition, other than the intitial decrease in IOP following induction of anesthesia, no consistent patterns of IOP change were evident for these patients (Figure 3). Neither patients who underwent CPB surgery nor those who underwent OP surgery showed a significant correlation between maximal IOP change and maximal change in BP, body temperature, pCO_2, hematocrit level, or pH.

DISCUSSION

Based on our data, there appears to be a statistically significant elevation in IOP during cardiac surgery performed with CPB. We also found that a preoperative IOP of 15 mm Hg or greater was a statistically significant predictor of an increase in IOP shortly after initiation of CPB. The study's small sample size and variability in IOP measures between time

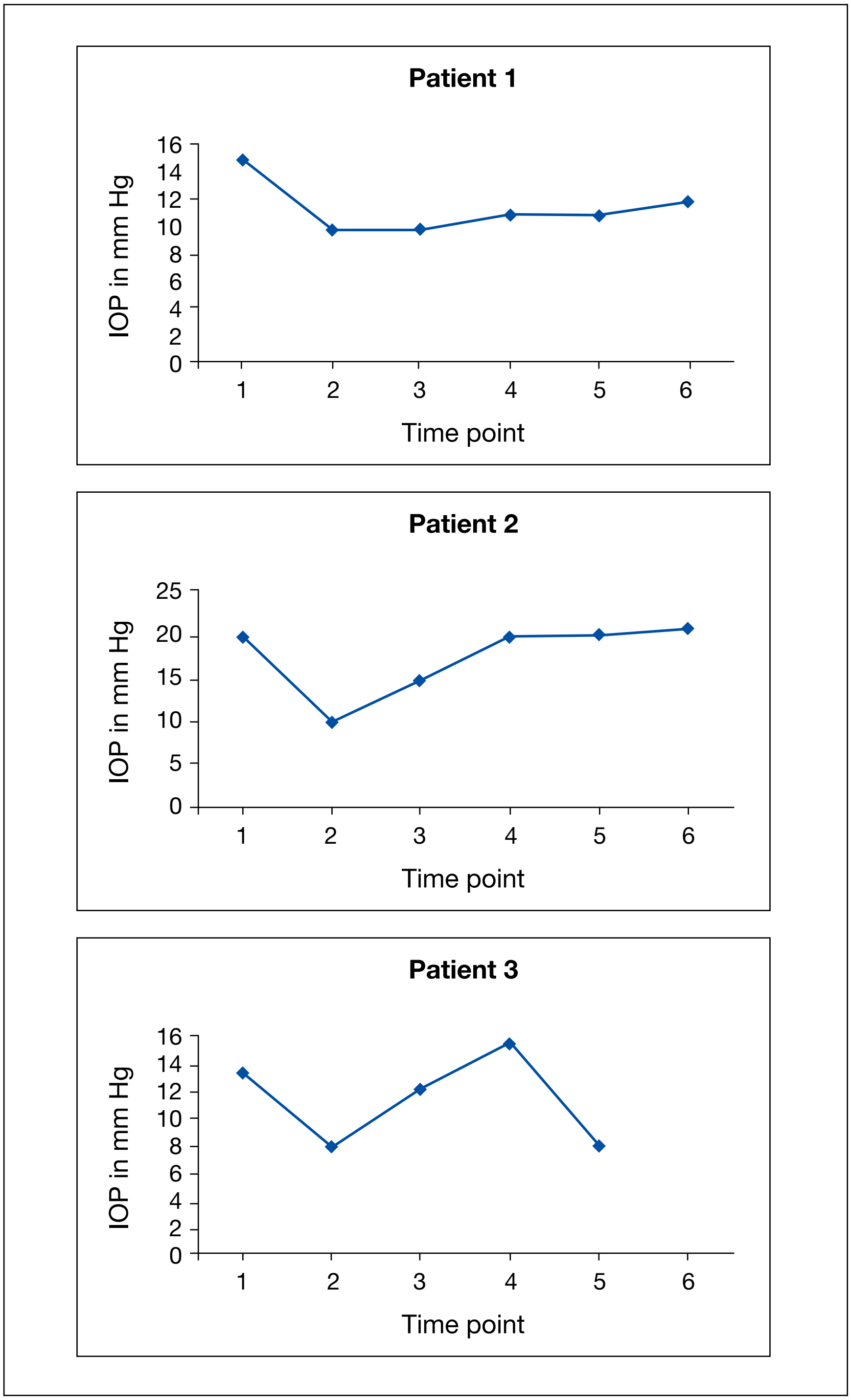

Figure 3. Intraocular pressure (IOP) variation in three patients who underwent off-pump cardiac surgery, demonstrating the absence of a consistent pattern of IOP changes in the patients who underwent this surgery. Time points are as follows: 1 = preintubation, 2 = postanesthetic, 3 = prepositioning, 4 = postpositioning, 5 = postrepositioning, 6 = postreperfusion.

points in individual patients, however, make definitive conclusions regarding these findings difficult.

The absence of significant IOP changes that we observed in patients undergoing OP surgery may explain the very low incidence of postoperative AION detected in these patients overall. It also is worth noting that several studies[17–20] have shown a significantly lower incidence of postoperative cognitive impairment in patients undergoing OP cardiac surgery than in patients undergoing CPB cardiac surgery. As the use of OP cardiac surgery increases, more data will be available for analysis.

As noted earlier, OP cardiac surgery is associated with hemodynamic instability secondary to required changes in the position of the heart or the patient during an attempt to provide access to the target coronary artery.[21] No effect of positional changes on IOP, however, was demonstrable in our study.

Although none of the patients enrolled in the study reported visual symptoms during the immediate postoperative period, cardiac surgery has been associated with numerous postsurgical complications to the eye—some of which have no symptoms. It is possible that asymptomatic complications after surgery may have been missed. This possibility does not, however, alter the findings of a statistically significant relationship between IOP changes during CPB cardiac surgery.

IN CONCLUSION

As our results show that statistically significant IOP elevations occurred during CPB cardiac surgery but not during OP cardiac surgery, the relationship between IOP elevation after CPB and the increased risk of AION in CPB heart surgery warrant further study. The possibility that lowering preoperative IOP could reduce the IOP elevation noted during CPB also merits investigation. ●

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