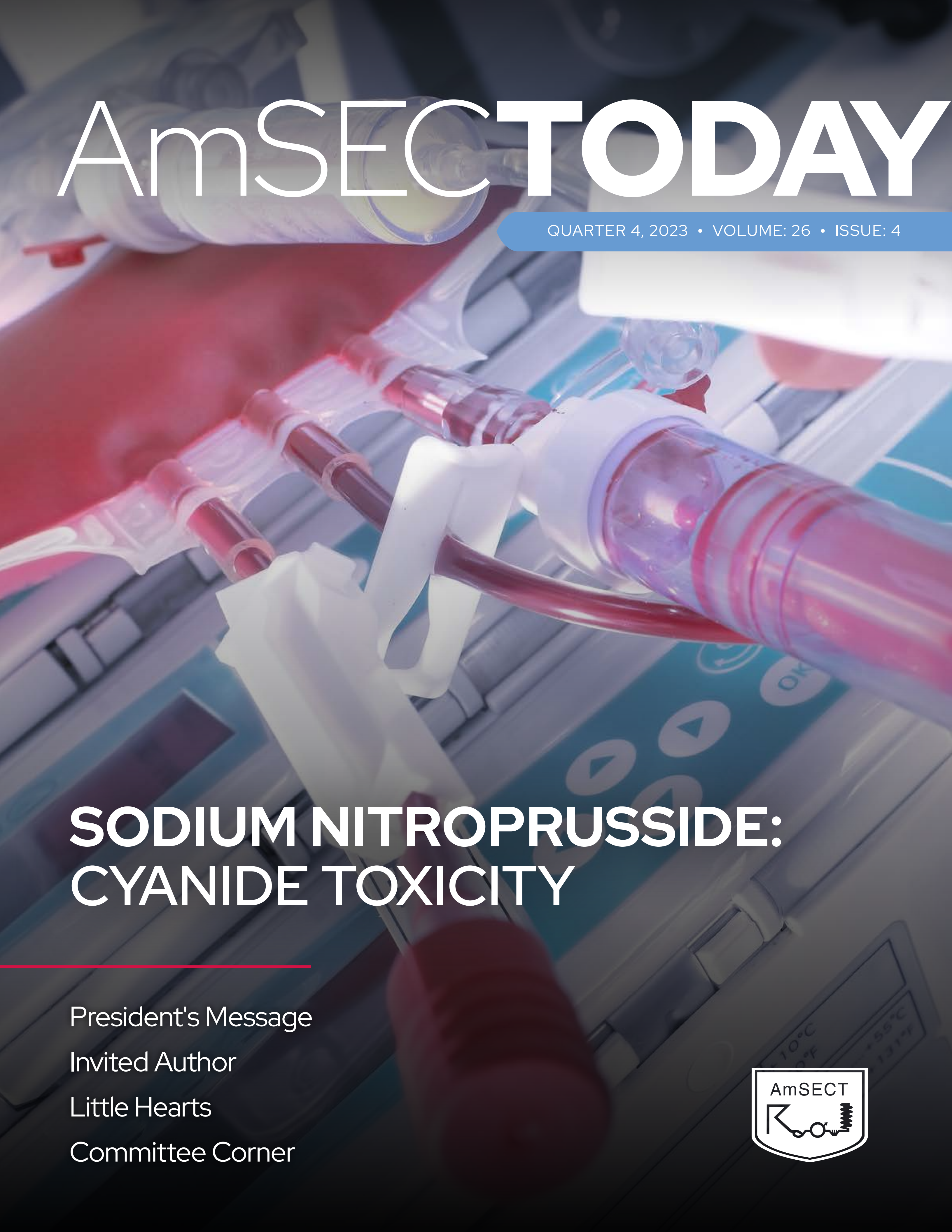

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QUARTER 4, 2023 • VOLUME: 26 • ISSUE: 4

SODIUM NITROPRUSSIDE: CYANIDE TOXICITY

AmSECT

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SODIUM NITROPRUSSIDE: CYANIDE TOXICITY

Alexander Skaalen, NRP FP-C

COLUMNS

YOUR OPINION MATTERS

As we have moved through fall and the holiday season, it reminds me that we constantly see change in our work and personal lives. One definition for change is "to give a different position, course, or direction to" (www.merriam-webster.com).

AmSECT has recently launched a campaign called "Your Opinion Matters." Surveys will be sent out quarterly to members via email to ensure AmSECT stays on the best "course or direction" for its members. The only way for AmSECT to meet the needs of its members and the Perfusion community is by understanding Perfusionists' needs and interests. The Board of Directors wants to hear from you on each survey so we can best align for and deliver what is important to you.

The first survey in the series is regarding this publication, *AmSECToday*, and we thank you for your participation. If you have not had a chance to participate in the survey you can grab the link from the last page of this newsletter. You will also be emailed another opportunity at the beginning of the year. More surveys will follow. We appreciate your participation in each and every one and, most importantly, your commitment to our profession.

AmSECT is what it is today because of its membership. Thank you in advance for your participation and continued support of AmSECT and our profession!

Tami Rosenthal, *MBA CCP FPP*

THE ONLY WAY FOR AMSECT TO MEET THE NEEDS OF ITS MEMBERS AND THE PERFUSION COMMUNITY IS BY UNDERSTANDING PERFUSIONISTS' NEEDS AND INTERESTS.

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To submit news items, story ideas or manuscripts for publication consideration, contact the editors via email (see contact information above).

SODIUM NITROPRUSSIDE: CYANIDE TOXICITY

Alexander Skaalen, NRP FP-C

Pharmacological management of blood pressure and hemodynamics remains vital for anesthesiologists and perfusionists during cardiac surgery. Sodium Nitroprusside was FDA-approved for the treatment of hypertensive crisis in 1974 and, in 1993, gained widespread popularity due to its immediate action and short duration in the body. With several newer, less toxic medications available on the market, such as calcium channel blockers, the role of Sodium Nitroprusside has decreased in the operating room suite. However, it is still a valuable tool for treating and managing hypertension. In this article, we will look at what Sodium Nitroprusside is, how it works, cyanide toxicity, and treatment of cyanide toxicity on cardiopulmonary bypass.

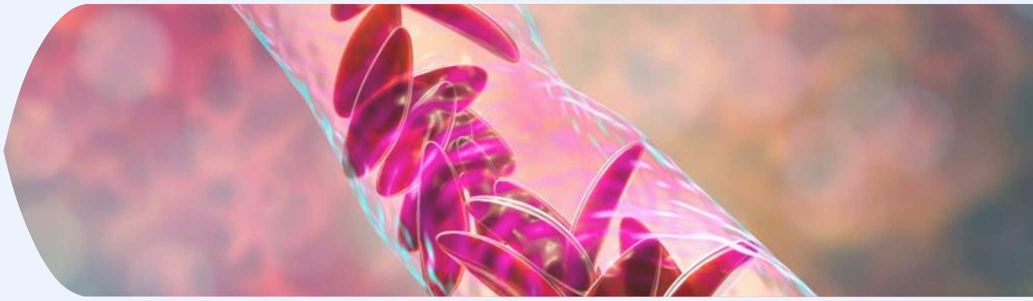
Sodium Nitroprusside is a potent, fast-acting vasodilating anti-hypertensive agent. Sodium Nitroprusside (SNP) is a water-soluble ferrous iron salt with nitric oxide and five cyanide ions.[1] The vasodilatory property of SNP comes from the production of nitric oxide through reactions with sulfhydryl groups that are present on erythrocytes, as well as other proteins. This reaction's nitric oxide production triggers intracellular cGMP-mediated activation of protein kinase G and inactivates myosin light chains. This prodrug reaction causes smooth vascular relaxation, and arterial and venous dilation. SNP's short active duration in the body makes precise titration of the medication ideal. FDA-approved indications for SNP include acute hypertensive crisis, acute decompensated heart failure, and inducing perioperative hypotension to reduce blood loss. Sodium Nitroprusside reduces systemic vascular resistance and afterload, reduces ventricular filling pressures, reducing systemic blood pressure, and increasing cardiac output.[2,3]

As SNP reacts with sulfhydryl groups on erythrocytes, free cyanide is released, with four cyanide molecules being converted into thiocyanate and one cyanide molecule being detoxified by the liver. The liver can quickly become overwhelmed, and free cyanide will start to accumulate. From a list of patients at higher risk of developing cyanide toxicity, patients on cardiopulmonary bypass are among those at risk. Studies have shown that SNP favors sulfhydryl groups on hemoglobin to release free cyanide. Hemolysis occurring during cardiopulmonary bypass has been shown to potentiate the release of free cyanide five to eight times more than non-lysed hemoglobin. Researchers tested this with nitric oxide and SNP with lysed and non-lysed blood. The results showed that the intact erythrocyte membrane better limited the reaction and release of cyanide than when the membrane was damaged and hemolysis occurred.[4]

Cyanide toxicity causes tissue hypoxia, even when there is adequate PO_2 present. Identifying cyanide toxicity can be challenging during surgery for the anesthesiologist, which is an essential reason for the perfusionist to be aware of

WHEN CYANIDE TOXICITY OCCURS, OXYGEN SATURATIONS ON ANESTHESIA'S MONITOR CAN STILL SHOW 100 PERCENT, AND CYANOSIS WOULD NOT BE PRESENT.

the signs of cyanide toxicity and be able to respond appropriately. Perfusionists must notify the anesthesiologist of their findings and work together to provide adequate treatment properly. Standard cyanide toxicity results in high levels of oxygen in the blood but prevents the utilization of oxygen by the body. When cyanide toxicity occurs, oxygen saturations on anesthesia's monitor can still show 100 percent, and cyanosis would not be present. In fact, patients with cyanide toxicity often present with cherry-red skin. Cyanide toxicity can cause bradycardia and a state of unconsciousness. Based on these clinical features in a patient under general anesthesia and on cardiopulmonary bypass, detecting cyanide toxicity would be challenging. During cyanide toxicity, the rapid accumulation of cyanide ions builds up in the body, causing cytochrome oxidase inactivation. This inactivation prevents mitochondrial oxidative phosphorylation and leads to the inhibition of cellular respiration, causing tissue hypoxia. The loss of mitochondrial oxidative phosphorylation leads to the cessation of ATP production, resulting in death.[5]



Signs of cyanide toxicity on cardiopulmonary bypass include a rise in mixed venous PO_2 with a rise in CO_2, metabolic acidosis, and bright red blood returning in the venous line, matching the color of the blood leaving the oxygenator in the arterial line, as the body's tissues are not utilizing oxygen. Once suspected, immediate communication of your findings should be communicated with anesthesia and the surgical team, and if still being infused, the Sodium Nitroprusside infusion should be stopped immediately. The perfusionist should maximize oxygenation by increasing the FiO_2 to 100%. The treatment of cyanide toxicity is hydroxocobalamin, which binds cyanide to produce cyanocobalamin. Cyanocobalamin does not have adverse effects and does not produce methemoglobin. Sodium thiosulfate can be administered to facilitate the metabolic removal of cyanide as thiocyanate through the kidneys. Another treatment option is creating methemoglobin that can combine with the cyanide, producing cyanomethemoglobin, and removing cyanide from cytochrome oxidase.[6] Perfusionists should be aware of all the medication infusions being utilized during a cardiopulmonary bypass run and understand how these medications interact. If an institution utilizes SNP for the management of hypertension, reduction of bleeding, or as an arterial vasodilator, cyanide toxicity should be in the back of your mind so that you can respond effectively.

Acknowledgments

Andrew Feider, MD, associate professor and division director of cardiothoracic anesthesia at the University of Iowa Hospitals and Clinics and University of Iowa Carver College of Medicine, was consulted for this article.

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CHOOSING THE OPTIMAL CEREBRAL PERFUSION STRATEGY IN COMPLEX AORTIC CASES: GLOBAL CLINICAL PRACTICE INSIGHTS

Salman Pervaiz Butt, MBA MSc MPHYS CES-A E-AEC ACCP FCCP

Introduction

Deep hypothermic circulatory arrest (DHCA) is used in complex surgeries to pause circulation temporarily while providing optimal operating conditions and protecting the brain from ischemic damage. Patients can generally tolerate around 30 minutes of DHCA at 18-20°C without significant neurological issues, but longer durations increase the risk of brain injury.

DHCA necessitates meticulous preoperative assessment, monitoring, and careful rewarming after the procedure. Although their efficacy varies, pharmacological neuroprotection and glycemic control are to be considered. Surgical techniques like selective antegrade cerebral perfusion (SACP) and retrograde cerebral perfusion (RCP) can extend DHCA's safety duration. Postoperatively, patients require close ICU monitoring to manage complications. Despite its benefits, DHCA carries risks, including mortality and cognitive dysfunction, especially in adults.[1]

This article delves into various approaches for cerebral protection during complex aortic surgery. Despite years of experience with complex aortic surgery, we have yet to pinpoint the definitive optimal technique.[1] Our exploration involved conducting a concise survey to shed light on the rationale behind diverse techniques employed by different operators. We also examined the merits and drawbacks of these techniques.

Antegrade Cerebral Perfusion

Antegrade cerebral perfusion (ACP) is a technique where the application varies based on factors like perfusion pressure, flow rates, temperature, pH management, hematocrit values, cannulation sites, and unilateral versus bilateral use. Human brain metabolism and blood flow regulation are essential considerations. Animal studies have explored factors like pH management and hematocrit values, showing potential impacts on cerebral protection. Clinical studies have reported variations in ACP flow, pressure, and temperature settings, with bilateral and unilateral applications yielding similar outcomes. Cannulation sites, such as subclavian, carotid, and axillary arteries, each have advantages and risks. Lower body ischemia is a concern at higher temperatures, emphasizing the importance of distal aortic perfusion.

Current ACP practice often involves unilateral perfusion through the right subclavian artery or bilateral perfusion through the left carotid artery with ACP using a flow of 10 mL/kg/min at 24°C to maintain a pressure of 50 mmHg.

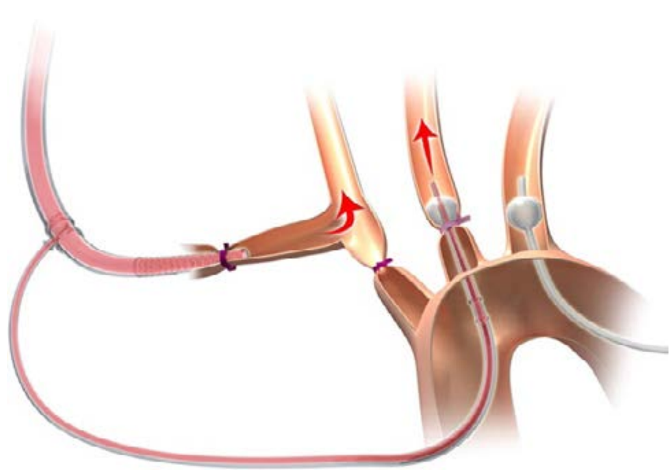


Figure 1. Illustration of Antegrade Cerebral Perfusion[4]

Overall, ACP is becoming more common in aortic surgery, with satisfactory results in current applications, but the need for further prospective trials remains a subject of discussion.[2,3]

Retrograde Cerebral Perfusion

Retrograde cerebral perfusion (RCP) is commonly employed in complex aortic and related surgical procedures to safeguard cerebral oxygenation and prevent ischemic harm to the brain. RCP is delivered through an SVC cannula. Once DHCA is successfully induced, RCP is initiated, with strict adherence to recommended flow rates, temperature levels, pressure parameters, and cerebral saturation targets. Maintaining a retrograde flow rate within a 300-500 ml/

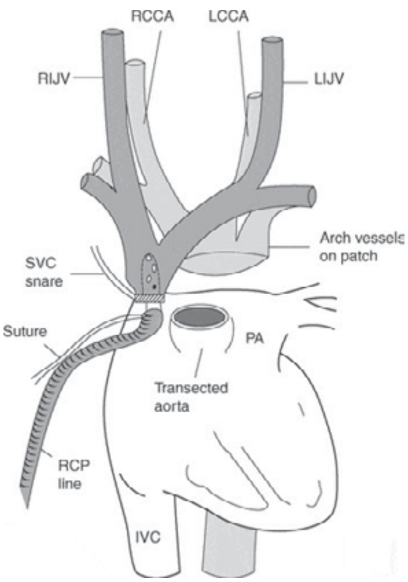


Figure 2. Illustration of Retrograde Cerebral Perfusion[10]

min range is pivotal for ensuring adequate cerebral perfusion. Continuous monitoring of key metrics, including SVC pressure, perfusate temperature, cerebral oxygen saturation, and arterial blood gases, is essential throughout the procedure.

Retrograde cerebral perfusion (RCP) aids in maintaining cerebral cooling and extends the safe DHCA duration. However, while RCP is vital for cerebral perfusion and oxygenation, it carries risks and complications — such as cerebral edema, inadequate flow to meet metabolic demands, uneven distribution in brain microvasculature, and variable oxygen delivery due to shunts. Vigilant monitoring and management are essential to optimize the benefits of RCP while minimizing potential drawbacks in DHCA procedures.[5,6,7,8,9]

RCP serves a critical role not only in complex aortic procedures but also in non-aortic surgical procedures such as Pulmonary thrombo-endarterectomy (PTE) and plays a pivotal role in addressing emergency scenarios involving massive air embolism troubleshooting.[11,12]

Clinical Practice: LinkedIn Poll on Cerebral Protection Strategies in Complex Aortic Surgery

A LinkedIn Survey was performed by running a seven-day poll regarding cerebral protection strategy during complex aortic surgery worldwide, asking a simple question: **Which strategy do you use for Cerebral Protection during complex aortic Surgery?**

This survey sought to understand the preferences and practices of healthcare professionals in choosing cerebral protection strategies during these procedures. The survey offered three options: Antegrade Cerebral Perfusion (ACP), Retrograde Cerebral Perfusion (RCP), and Deep Hypothermic Circulatory Arrest (DHCA) Only.

Survey Results:

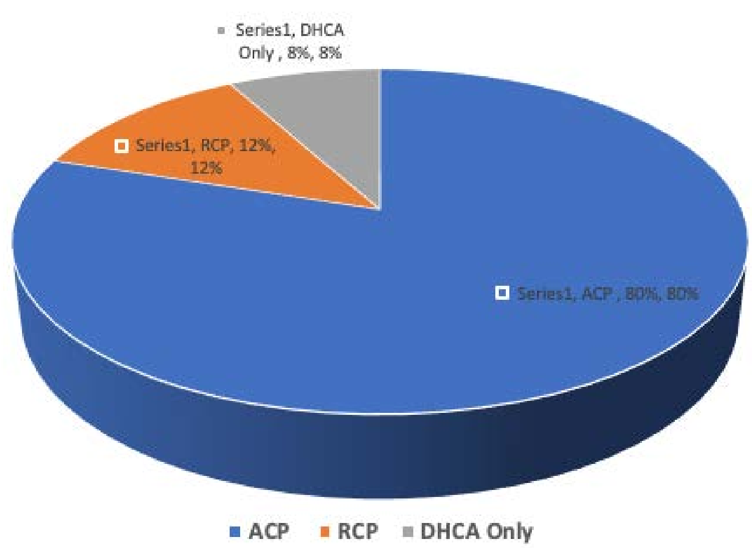
A total of 187 individuals participated in the survey, and the results are as follows:

1. **Antegrade Cerebral Perfusion (ACP):** 80%
2. **Retrograde Cerebral Perfusion (RCP):** 12%
3. **DHCA Only:** 8%

Survey Analysis

The survey findings reveal distinct preferences among healthcare professionals regarding the three primary techniques of cerebral protection during complex aortic surgery. Antegrade Cerebral Perfusion (ACP) emerges as the dominant choice, commanding an overwhelming 80% preference. This strong inclination toward ACP underscores its popularity among the surveyed group and suggests a consensus on the importance of continuous brain oxygenation during such procedures. One major benefit of ACP is its ability to ensure a consistent supply of oxygenated blood to the brain throughout the surgery. Moreover, it enables precise control of brain temperature, thereby reducing the risk of ischemic injury.

In contrast, Retrograde Cerebral Perfusion (RCP) garners a significantly smaller share of the vote, with only 12% of survey participants opting for this technique. While less favored, RCP has its merits, particularly in situations where lowering aortic pressure is critical, such as in aortic dissections. Its relative simplicity and potential cost-effectiveness may contribute to its selection by some healthcare professionals. However, it is essential to note that RCP demands precise coordination



and vigilant monitoring to ensure optimal outcomes. Surgeons must carefully weigh the advantages of RCP against the associated risks.

Last, the survey indicates a minimal preference for relying solely on Deep Hypothermic Circulatory Arrest (DHCA), with only 8% of respondents favoring this approach. The low preference for DHCA-only suggests that it is not considered a viable standalone option for most complex aortic procedures. This is primarily due to the inherent risks associated with prolonged circulatory arrest and the potential for neurological complications. Healthcare professionals seem cautious about relying solely on DHCA for cerebral protection, highlighting the need for alternative or supplementary methods. In summary, the survey findings underscore the diversity of strategies employed in complex aortic surgery, with ACP emerging as the dominant choice, RCP as a minority preference, and DHCA-only as the least favored option among healthcare professionals.

Conclusion

In conclusion, cerebral protection techniques during complex aortic surgery are more commonly employed than not. The survey results demonstrate a strong preference for ACP, highlighting its role in ensuring consistent brain oxygenation and reduced risk of ischemic injury. While RCP and Deep Hypothermic Circulatory Arrest Only (DHCA-only) have their merits, they are less favored due to specific challenges and risks. The survey results and reviewed literature underscore the need to refine and optimize cerebral protection strategies in complex aortic and non-aortic surgeries.

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PERFUSION PAY, PART ONE: TRANSPARENCY

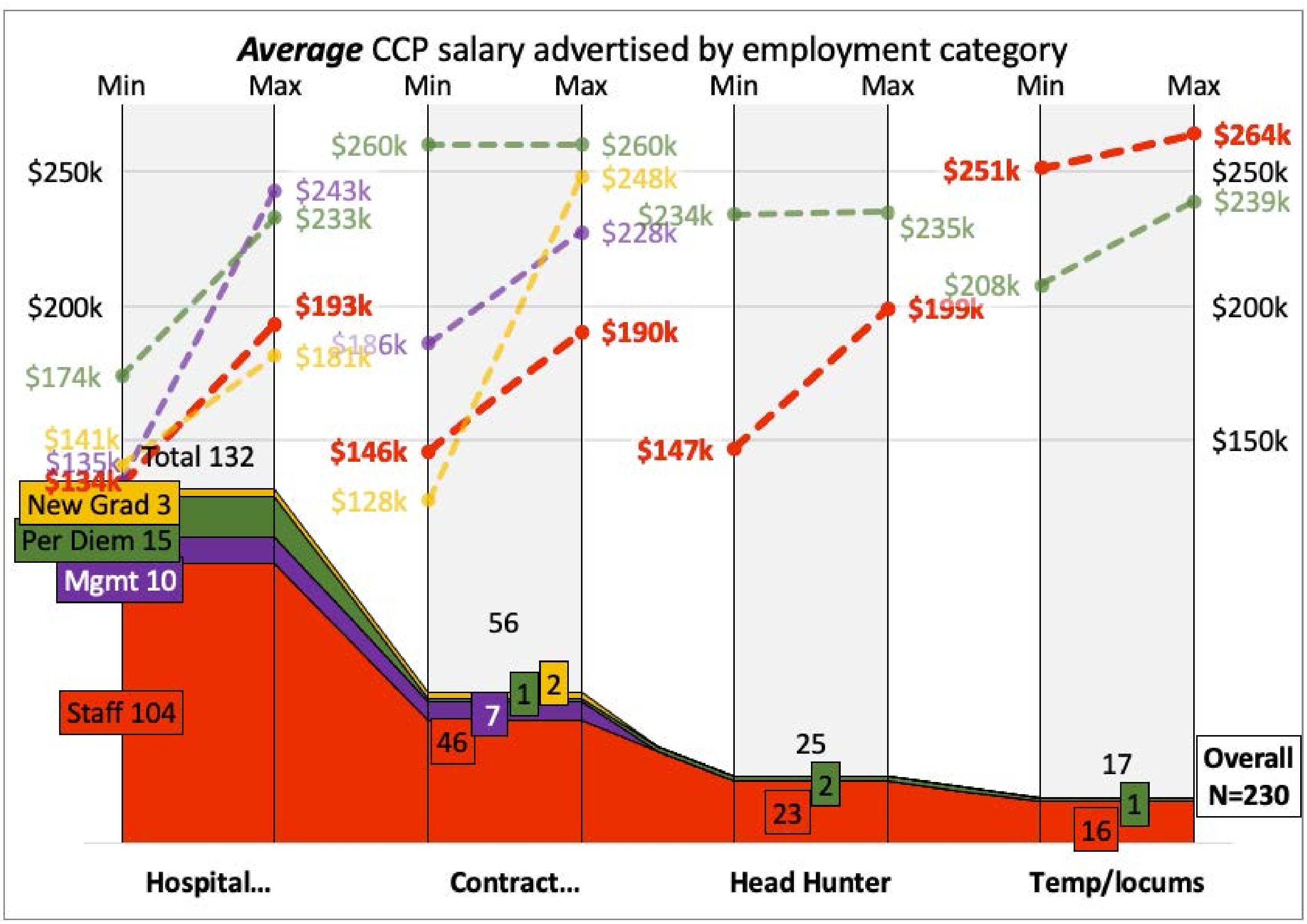
Brent Thye, CCP

Pay transparency is fast becoming law in many jurisdictions, seeking to assure pay equity and providing a window into what salaries are offered. While no position should be sought solely for its salary, it is always a factor in the decision calculus of applicants and candidates offered a position.

Only four states *require* a pay range to be included in publicly posted job advertisements: Colorado, California, New York, and Washington. Hawaii (01/2024) and Illinois (01/2025) have passed legislation to implement it at a future date. Though small in number, these states hold outsize influence as they represent around 25% of the entire population of the US. In other states, whether employers post their pay range in job postings is optional. Once a critical mass of employers chooses or is required to post their pay range, it may become disadvantageous for those who continue to speak in platitudes of "competitive" pay in lieu of providing concrete ranges.

A movement in the making

Pay transparency is a relatively young concept, rooted in the 1935 National Labor Relations Act (NLRA) and the 1963 Equal Pay Act passed by Congress. The NLRA prohibited employers from retaliating against employees who discussed their own pay. The Equal Pay Act prohibited discrimination based on sex, though it was silent on other forms of discrimination. Still, according to Pew Research, "In 2022, Black women earned 70% as much as White men and Hispanic women earned only 65% as



much. The ratio for White women stood at 83%, about the same as the earnings gap overall, while Asian women were closer to parity with White men, making 93% as much." A central argument is that the Equal Pay Act is a compliance and enforcement mechanism with pay information generally remaining a black box to individuals. To this end, pay transparency burdens employers to establish, disclose, and maintain uniform pay scales, ideally eliminating the gender and racial pay gaps. This gives employees greater visibility into their current or prospective employers' pay practices and allows them to negotiate for a higher salary when they feel they are not being fairly compensated. Some current laws include a reporting component to the state to verify that employers are not discriminating between employees. However, there is no mechanism to allow individuals to see the salary or pay of others to verify this for themselves. Radical Transparency is where the pay of all employees is openly shared. This extreme level of transparency is not widely embraced and is usually found in governmental and some tech sector employers.

Caveat Emptor

The data presented here were obtained by simply observing public job postings since January 2023. While some postings may accurately reflect the total earnings range, base pay is rarely the same as total earnings. However, a minuscule number of postings mention pay enhancements such as overtime, call pay, awards, bonuses, or other extra compensation. A typical policy of employers is to start new hires only up to a certain step in a pay scale, no matter how experienced, to help reward the longevity of current employees. How each employer sets their scale is opaque, with no way to tell if the range posted reflects the top of the employer's scale for the position. This means salaries may extend well beyond what is posted, or they may not. It's also impossible to elucidate what offers are *actually* extended to candidates. For these reasons and others, the data reported below should be used only to gain perspective. While it is informative, it is not definitive data.

A Disclosure Observation

Outside of required states, the employers more likely to display pay ranges are those that are prestigious in terms of pay. Two national employers, "Co. A" and "Co. B," exemplify this phenomenon. They both posted lower salaries in required states: Everett, WA, $102k-$165k (Co. A) and Denver, CO, $110k-$165k (Co. B). In *optional* states, both rarely post salaries they offer, but when they do, they are in the upper echelons: Carrolton, GA, $200k (Co. A) and Winchester, VA, $180k-$190k (Co. B, management position). Not to say anything about the cost of living in these locales.

$151,534-$205,598 is the average posted salary range for *all* Perfusionist positions, covering 230 unique public job postings since January 2023. The initial average seems simple enough, but there is much more here than meets the eye.

The data will be broken down along the following lines: hospital employed or contract group; permanent, temporary, or headhunter advertisements; new grad, staff, management, or per diem positions. These different categories generally follow some expected contours: Per diem and temporary are paid the highest due to their itinerant nature, management makes more than staff, and headhunters offer a bit more over direct hiring as filling a position is their primary interest over the long-term costs associated with higher salaries. There are so few new-grad-specific positions (n=5) that this category is functionally insignificant.

$137,741-$192,352 is the average posted pay range for full-time *permanent staff* positions employed directly by a hospital or contract group. This group comprises the lion's share, 145 of 222 (65%), of all positions posted, making this cohort the basis for comparing apples-to-apples. The following sections contemplate data only for full-time staff positions employed directly by a hospital or contract group.

Table 1

City	St	Employer	Min CCP	Max CCP	Min RN(%ccp)	Max RN(%ccp)	Min APP(%ccp)	Max APP(%ccp)
Roslyn	NY	Hospital	**$216,320**	**$312,000**	$103k(48%)	$155k(50%)	$131k(61%)	$185k(60%)
Toledo	OH	Contract	**$205,000**	$205,000	$62k(30%)	$78k(38%)	$110k(54%)	$142k(69%)
Los Angeles	CA	Hospital	$196,082	**$292,136**	$117k(60%)	$175k(60%)	$146k(75%)	$197k(68%)
Tacoma	WA	Hospital	**$130,020**	**$188,531**	$85k(65%)	$143k(76%)	$126k(97%)	$163k(87%)
Salt Lake	UT	Hospital	**$130,000**	$230,000	$63k(49%)	$90k(39%)	$94k(73%)	$146k(64%)
Baltimore	MD	Contract	$101,800	**$187,100**	$62k(62%)	$110k(59%)	$116k(115%)	$148k(79%)
Ft Myers	FL	Contract	$130,000	**$140,000**	-----------	------------	------------	------------
San Antonio	TX	Hospital	**$86,273**	**$121,429**	-----------	------------	------------	------------
Memphis	TN	Hospital	$82,830	**$107,680**	$71k(86%)	$126k(117%)	$74k(89%)	$130k(121%)

How We Compare with Other Professions

Perfusionists work alongside many other professionals with comparable educational requirements and job responsibilities, such as Registered Nurses (RN) and Advanced Practice Providers (APP). So, it is only natural to compare our apples to their oranges. Stated salary ranges, when available, were collected for RN and APP positions advertised *at the same facility* as the listed perfusion position. Assuming comparable experience, perfusionists generally have a higher pay scale, with the average RN's pay scale at **67%** and APP's at **90%** of the average permanent staff perfusionist's pay scale. Comparing hospital-employed to contract-employed permanent staff positions shows that contract groups tended to have a higher minimum starting pay, but their scale is not as wide. On average, the hospital-employed perfusionist maintains a consistent premium over RNs and APPs. Contract-employed do not; their minimum is above their counterparts, but their maximum shows they do not keep pace with the progressive wage scales of RNs or APPs, falling under APPs in absolute terms.

To put a finer point on it, here is a table with the **bolded numbers** indicating the maximum, median, and minimum posted ranges along with RN and APP ranges (including percentage of CCP pay), if available. (See previous page, Table 1.)

How We Compare with Other Professions: Cost of Living Adjusted

The preceding salary table is based on absolute dollars. While a valid comparison, absolute dollars fail to capture anything about the cost of living at any given location. To help digest what that means in practice, housing cost will be used as a proxy for the cost of living because a mortgage payment consumes a highly variable but substantial portion of monthly income, and rents tend to move in lockstep with housing prices. The methodology is: 1. Draw a 20-mile radius circle around the hospital. 2. Find every house sold recently in that circle and arrange by price. 3. Select the house at the 66th percentile. Flaws notwithstanding, it provides a foundation to evaluate each position better. Table 2 indicates the highest, median, and lowest cost of housing, along with the associated pay ranges.

This table purports to show that the correlation between the advertised pay range and the cost of housing is weak at best. Graphing minimum advertised pay versus housing cost of all permanent staff positions and their matching RN and APP positions provides further evidence supporting this rather disconcerting conclusion. You can see in the graph that the RN (in green) and APP (in blue) both produce linear fit lines with nearly equal slopes of ~0.05, whereas the CCP linear fit line in red has a much lower slope of 0.025. This means that RN and APP pay ranges scale up at **double** the rate of CCP pay ranges as housing prices climb. In practice, for every $100k increase in house price from area to area, RNs and APPs will earn $5,000 more per year, whereas CCPs will only gain $2,500 per year for that same home price hike. While there are myriad reasons why individuals choose to live and work where they do, the cost of living and the trade-offs it entails are significant facets that should not be discounted in pay equity discussions.

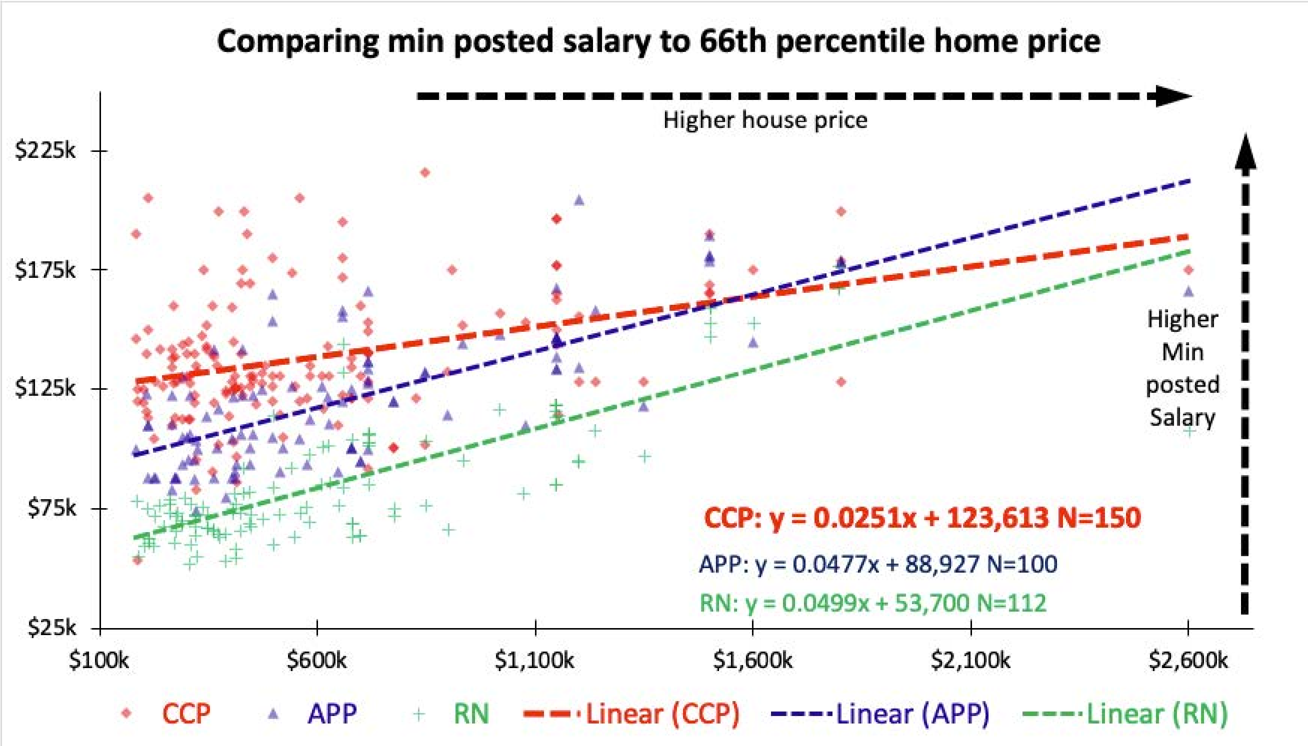
Conclusions

This last point hopefully helps the nascent pay transparency movement come into sharper focus on what it can look like in practice for perfusionists. The movement helps break down pay equity barriers and establishes more uniform expectations that will benefit employers and employees. For the same reasons transparency is now required in several states, I have suggested to AmSECT that the same degree of pay transparency should be required for all positions posted on the AmSECT website job section. I hope that others agree, but this is still a nascent movement.

In a future issue of *AmSECToday*, I will discuss my research presented at the CREF™ (Cardiothoracic Research and Education Forum) meeting in September 2023. We will look at publicly available data to understand how a base salary offered translates into total pay received and discuss current trends. While base and total

Table 2

City	St	Empl	$Home	CCP Min	CCP Max	RN(%ccp) Min	RN(%ccp) Max	APP(%ccp) Min	APP(%ccp) Max
Santa Barbara	CA	Hosp	$2.6m	$175,040	$262,560	$107k(62%)	$161k(62%)	$166k(95%)	$201k(77%)
Palo Alto	CA	Hosp	$1.8m	$199,742	$232,876	$168k(84%)	$194k(83%)	$179k(89%)	$218k(83%)
San Jose	CA	Contr	$1.8m	$127,600	$204,100	$166k(131%)	$229k(112%)	$179k(140%)	$236k(116%)
Pomona	NJ	Contr	$445k	$170,000	$190,000	-----------	-----------	-----------	-----------
Houston	TX	Hosp	$445k	$130,020	$188,531	$68k(52%)	$109k(58%)	$93k(72%)	$148k(79%)
Johnson City	NY	Hosp	$185k	$145,891	$218,899	$77k(53%)	$123k(56%)	$99k(103%)	$149k(101%)
Ashland	KY	Contr	$185k	$190,000	-----------	-----------	-----------	-----------	-----------



compensation are interrelated, they are far from interchangeable topics, as the trends themselves will reveal!

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Brent Thye, CCP, is a practicing perfusionist and in previous lives he was a flight paramedic, park ranger, helicopter pilot, and Eagle Scout. Direct your feedback to perfusionpay@gmail.com.

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TRIAL AND ERROR: MAPCAS

By Gary Grist, BS RN CCP Emeritus

The saga of dealing with MAPCAs (Major Aortic to Pulmonary Collateral Arteries) on CPB goes back to the early use of CPB for open heart surgery. It has been a long and difficult learning curve, especially for the patients. It is one of those unfortunate circumstances where we learned by trial and error over many years, during which time the patients (or their parents) had complete but unjustified confidence in the surgeon and cardiac team. Unjustified because surgeons and perfusionists *did not know what they did not know.* When I started in pediatrics in 1981, I did not know what MAPCAs were. I am not proud of my results back then. And my surgeons were not much help in offering advice. Indeed, the realization that MAPCAs were important was just coming to the forefront less than a decade earlier. After a quick search, these are four of the earliest articles I could find on what we now call MAPCAs.[1,2,3,4] And there was no hint of how these patients should be pumped. Whatever older perfusionists had learned in those early years about dealing with MAPCAs, they did not share with the perfusion community by publishing their experiences.

Not All Perfusionists Are Qualified

Nowadays, experienced pediatric perfusionists are well-versed in using CPB on MAPCA patients; adult perfusionists, not so much. But as congenital patients grow older, they will require additional surgery for revision or for acquired disease. Not all perfusionists are qualified by training or experience to pump MAPCA cases, but they may be pressed into it by circumstance. The adult perfusionist faced with the MAPCA patient may be unaware of the dreadful ramifications that can ensue. CPB may appear to work well during these cases, while a devastating outcome may develop in reality. Proximal aortic cannulation may cause poor perfusion below the diaphragm. Femoral arterial cannulation may cause poor perfusion above the diaphragm. Ventricular vent overload may present additional problems. The patient's bad outcome might be incorrectly attributed to poor patient selection or other high-risk circumstances. But in reality, the perfusion methods used (or not used) may contribute substantially to post-operative morbidity without the perfusionist even being aware. Balloon pumps will not work well on these patients and ECMO management will be a great challenge.

MAPCA Anticipation

MAPCAs are most often present in patients with congenital hypoxic cardiac lesions. They grow spontaneously during fetal development to provide additional blood flow to the lungs.

Friends,

This will be my last article under the moniker "From My Time in the Trenches." I have been contributing articles to *AmSECToday* since 1998. In those articles, I tried to share my experiences and any wisdom I acquired during my 45+ years as a perfusionist. But, we are well into a new century and I hope a new columnist with younger blood will step up to take my place. I plan to continue to contribute to history articles as a member of the AmSECT History Committee. And, after 45+ years behind the pump and 9 years in retirement, that is where I belong now...in history.

Best wishes to you all and may God protect you and your patients.

Gary

This results in a significant systemic to pulmonary shunt after birth that can reduce effective systemic blood flow during CPB. MAPCAs can be anticipated in any hypoxic lesion patient, but are most often present in patients with pulmonary artery atresia, hypoplastic right and left hearts, any other univentricular anatomy, or Tetralogy of Fallot with pulmonary atresia. They often originate from internal mammary arteries and other nearby systemic vessels. MAPCAs may or may not be detected by aortogram catheterization (Fig.1). And even then, just 9% of MAPCAs may be seen on aortography without selective injection, meaning they are under-quantified.[5] They may be present as large, readily identifiable vessels or as a large plexus of small, individually unidentifiable vessels, or a mix of the two.

Fig. 1 Aortogram showing MAPCAs-
"VSD with pulmonary atresia: Management issues"
S. Venkatesan, MD, "Expressions in Cardiology"

Older At-Risk Patients

Older patients at increased risk of MAPCA-related morbidity include the following:

1. Adults with hypoxic congenital heart disease are at elevated risk of having persistent MAPCAs, even if the lesion was palliated or repaired in childhood.
2. Fontan completion patients, particularly those older than two years and those who have failed a previous Fontan completion attempt.
3. Patients with limited pulmonary blood flow, but whose room air arterial hemoglobin saturation exceeds 75% AND whose existing R or L pulmonary arteries are smaller than normal for patient size or who have pulmonary artery pressures above 25 mmHg (6).
4. Patients who outgrow a homograft and need it revised.

A Deceiving Term

The term "Major… Arteries" is deceiving. It implies that these are large vessels between the aorta and lungs. True, that is often the case. And sometimes these vessels can be mapped at cath or with other imaging techniques. They can then be severed from the aorta by the surgeon, gathered, and affixed to whatever diminutive main pulmonary artery is present; a so-called unifocalization. But "Major" can also refer to the volume of blood these vessels carry rather than their anatomical size. Often the vessels are very small and individually indistinct, but very numerous. When the aorta is injected with dye at cath, these collaterals are seen as a hazy dye cloud moving from the aorta to the lungs. I think it looks like a puff of smoke. Just because the vessels aren't large and well-defined does not mean that the collateral blood flow they are carrying is small and inconsequential. Even if a unifocalization of the large vessels is successful, there may still be a significant collateral flow to the lungs from the smaller vessels not incorporated in the unifocalization. Further adding to the problem is the fact that the collaterals could be composed of either systemic or pulmonary tissue in different patients. This means that they vasoconstrict under different physiologic conditions, further adding to the perfusionist's difficulty in controlling the collateral blood flow.

NOT ALL PERFUSIONISTS ARE QUALIFIED BY TRAINING OR EXPERIENCE TO PUMP MAPCA CASES, BUT THEY MAY BE PRESSED INTO IT BY CIRCUMSTANCE.

Bloodless CPB

I discourage the use of bloodless CPB techniques that tolerate a lower-than-normal hematocrit in MAPCA patients. I know there are those who would vigorously disagree with me. It is my experience and educated opinion that, in these patients, the risk of brain damage due to under-perfusion is substantially higher than the ill-defined risk of an uncomplicated blood transfusion. I would assess an uncomplicated blood transfusion on CPB with a Harmfulness Risk Priority Number (RPN) of 2/5. But I would assess a Harmfulness score of 5/5 for MAPCA-related under-perfusion problems (1/5 being the least hazardous and 5/5 being the most hazardous). School-age children with MAPCAs who have undergone heart surgery earlier in their childhood have substantially more learning problems than normal children. I have no idea how much of this can be attributed to either brain damage from MAPCA-related under-perfusion before or during CPB or to any uncomplicated blood transfusion they may have received. In adults, MAPCA-related under-perfusion during CPB could conceivably accelerate other age-related health problems like chronic kidney failure, dementia, or even stroke if the patient survives the surgery. I have no specific proof of this, just a suspicion.[7]

Guidance

Only in recent years has there been written guidance to teach perfusionists how to pump a MAPCA patient. AmSECT does have a very specific protocol: *SUBJECT/TITLE: Pulmonary Artery Flow Study for Unifocalizations. "This protocol outlines the cardiovascular perfusionist's role and responsibility for the conduct of an intraoperative pulmonary flow study to determine the appropriateness of ventricular septal defect closure in the presence of pulmonary atresia and major aortopulmonary collaterals."* This has some good suggestions for pumping MAPCA patients. But it is incomplete. Margetson et al. have a recent, more complete description (2019) of the methods needed to address MAPCAs.[8] Many years ago (2011), I wrote a failure modes and effects analysis (FMEA) that describes the problem in detail and how I addressed it during CPB. If you would like to see this FMEA, go to Perfusiontheory.com*, select the Safety drop-down menu, select CPB FMEA, and scroll down to the letter I, item 3. All these guidances are good. Unfortunately, they were late in coming to benefit those early patients. But better late than never!

Interactive Fun

Stanford Children's Hospital has a fun, interactive animation that explains MAPCAs and allows the participant to perform a unifocalization surgery virtually.

https://www.stanfordchildrens.org/en/service/heart-center/unifocalization.page?utm_source=print&utm_medium=vanity&utm_campaign=vanity

The use of a homograft like that used in the animation in childhood guarantees the need for future surgical revisions using CPB. At that time, the perfusionist must again deal with any residual collaterals. The video says nothing about CPB technique for these patients. Nonetheless, I would have liked to have this video back in 1981.

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*Perfusiontheory.com is a free educational website.

Gary Grist, BS RN CCP Emeritus, was a perfusionist from 1968 through 2014 and is now retired from clinical practice. His career highlights include the AmSECT John H. Gibbon Jr. Award in 2023, the AmSECT Award of Excellence in 2015, the AmSECT Research Award in 2010 and the AmSECT Perfusionist of the Year in 2002. He served on the AmSECT Pediatric Perfusion Committee from 1997 to 2004. He was the associate editor of the *Journal of Extracorporeal Technology* from 2000 to 2014, an associate instructor at the School of Cardiopulmonary Perfusion at the University of Nebraska Medical Center from 1999 to 2014 and is currently a part-time adjunct instructor at the Lipscomb University School of Cardiovascular Perfusion.

PEDIATRIC DO_{2i}: WHAT DO WE KNOW, AND WHERE DO WE GO FROM HERE?

Molly O'Brien

Introduction

For both adult and pediatric patients undergoing cardiopulmonary bypass (CPB) during cardiac surgery, acute kidney injury (AKI) is one of the most common postoperative complications. Few modifiable risk factors predict the development of AKI, and recent research has focused on how nadir indexed oxygen delivery (DO_{2i}) on CPB could predict AKI development. Indexed oxygen delivery is calculated using the following equation: DO_{2i} = flow (L/min) x 10 x [Hgb (g/dL) x 1.36 x S_aO_2(%) + 0.003 x P_aO_2 (mmHg)] / BSA (m^2).

The management of patients on CPB using a target DO_{2i} has been termed goal-directed perfusion (GDP). The association between nadir DO_{2i} and cardiac surgery-associated AKI (CS-AKI) in adult patients has been assessed in randomized controlled trials, retrospective studies, and meta-analyses. Multiple studies, including the GIFT trial, point to an approximate 280 mL/min/m2 goal for adult patients.[11] More recently, studies have been published to assess the use of GDP in pediatric perfusion. However, the results have varied, and there is no current consensus on appropriate oxygen delivery goals for pediatric patients. Understanding the current data and its implications allow pediatric perfusionists to make more informed decisions about patient management.

Background

A primary goal of CPB is to maintain adequate perfusion to the body. To assess the adequacy of perfusion, perfusionists monitor many variables during bypass, including mean arterial pressure (MAP), pump flow rate, arterial and venous oxygen saturations, hematocrit, lactate, and regional near-infrared spectroscopy (NIRS). Over the years, various indicators, including lactate levels, venous oxygen saturation (S_v02), and DO_{2i}, have been investigated to assess how well they predict outcomes. Measurable outcomes include lactate level after CPB, development of cardiac surgery-associated AKI (CS-AKI), mortality, length of stay, and length of mechanical ventilation. CS-AKI is a straightforward postoperative complication to diagnose and has clear associations with poor outcomes, even in mild cases. AKI development increases the risk of mortality, costs of care, and the risk of developing chronic kidney disease.[2] A recent retrospective study confirmed that the occurrence of CS-AKI in children after CPB is associated with higher mortality rates and longer ICU stays and that improvement of AKI during hospital stay is associated with improved outcomes.[10]

As more data sets were published on assessing the adequacy of perfusion, a possible association between the nadir DO_{2i} on CPB and CS-AKI emerged. Much of the analysis of the effectiveness of GDP has been in adult cardiac surgical patients. Notably, the GIFT trial was a randomized controlled trial (RCT) that found a minor decrease in the occurrence of CS-AKI in low-risk cardiac surgical patients with a targeted nadir DO_{2i} greater than 280 mL/min/m^2.[11] The authors concluded that further studies are needed to investigate other modifiable factors that could reduce the incidence of CS-AKI.[11] A review article from 2023 included three clinical trials related to DO_{2i} with nadir DO_{2i} goals of 300 mL/min/m^2, 300 mL/min/m^2, and 280 mL/min/m^2.[7] The meta-analysis concluded that a GDP strategy reduced AKI stage 1 without affecting stages 2 and 3 or mortality.[7] In reviewing the body of evidence and expert opinion on preventing CS-AKI in adult patients, the PeriOperative Quality Initiative (POQI) and the Enhanced Recovery After Surgery Cardiac (ERAS) groups recommended a bundle of care during CPB, including a nadir DO2i goal of 280 mL/min/m^2.[2]

Fewer publications have presented data on how GDP applies to pediatric perfusion. Due to the recency of pediatric data, there is also a lack of meta-analyses and reviews on the body of evidence related to pediatric GDP. In addition, pediatric and congenital cardiac surgery program patients have a greater heterogeneity than adult patients. Patients can range in age from neonates to older adults with various cyanotic and acyanotic defects.

Discussion

There are three main definitions of AKI used in pediatric patients. Pediatric Risk, Injury, Loss, and End-stage renal disease (pRIFLE) defines AKI as more than a 50% decrease in estimated creatinine clearance or urine output less than 0.5 mL/kg/hour for 12 hours.[5] Acute Kidney Injury Network (AKIN) defines AKI as one or more of three criteria within 48 hours: absolute increase in serum creatinine (sCr) greater than 0.3 mg/dL, percentage increase in sCr greater than 50%, or oliguria with less than 0.5 mL/kg/hour for more than 6 hours.[5] Kidney Disease: Improving Global Outcomes (KDIGO) defines AKI as any of the following criteria: increase in sCr by greater than 0.3 mg/dL (26.5 mcmol/L) within 48 hours, increase in sCr to greater than 1.5 times baseline, or urine volume less than 0.5 mL/kg/hour for at least 6 hours.[5] In pediatric cardiac surgery, estimates of CS-AKI occurrence defined under any classification range from 30-64%.[4,6,16]

The retrospective and prospective cohort studies summarized below have found varying goals for target DO_{2i} to prevent CS-AKI. The five publications listed found a statistically significant association between nadir DO_{2i} and postoperative AKI development.

- In a study published in 2022, P. Zhang et al. analyzed data from 126 neonates undergoing an arterial switch operation with hypothermic CPB with target temperatures between 27° and 30°. A hypothermic nadir DO_{2i} above 269 mL/min/m^2 and a higher nadir CPB flow rate were both determined to be independent protective factors to prevent CS-AKI on the neonatal modified KDIGO scale. Even adjusted for MAP, the nadir flow rate was correlated with CS-AKI, leading the authors to conclude that, unlike adults, pediatric renal perfusion depends more on CPB flow than MAP.[15]
- A study published in 2022 by Gao et al. included 413 infants under 10 kg undergoing mild (32-34°) or moderate (26-32°) hypothermia during CPB. For mild hypothermia, a nadir DO_{2i} greater than 258 mL/min/m^2 during hypothermia and greater than 281 mL/min/m^2 for rewarming had predictive value in preventing AKI using the KDIGO criteria. The DO_{2i} during moderate hypothermia or rewarming from moderate hypothermia had no association with AKI.[6]
- A prospective cohort study published in 2022 by Y. Zhang et al. included 83 children from 1 month to 3 years of age undergoing CPB. The two independent risk factors for pRIFLE AKI development from their data were CPB duration and a nadir DO_{2i} less than 353 mL/min/m^2. The findings included that CS-AKI was associated with increased morbidity but not increased mortality.[16]
- A retrospective analysis of 396 pediatric patients (under 18 years of age) from April 2019 to April 2021 found a critical DO_{2i} threshold of 350 mL/min/m^2 for all stages of AKI using the KDIGO classification. An increased area under the curve increased the risk for AKI development. The authors also noted that further study is warranted to investigate individualized goals for cyanotic and acyanotic patients and the possible existence of a maximum DO_{2i} threshold. Other risk factors for AKI based on the Hayward et al.

study include younger age, longer CPB time, longer ischemic time, and higher inotropic support required post-operatively.[8]

- In 2023, Dreher et al. published a retrospective analysis of 1,234 infants under a year of age undergoing CPB between January 1, 2013, and January 1, 2020. Patients were divided by age (under and over one month), and STAT categories (1-3 and 4-5), and the KDIGO criteria were used to diagnose AKI. For neonates in STAT categories 4 and 5, 340 mL/min/m² was the nadir DO_{2i} to reduce CS-AKI risk. For infants in STAT categories 1-3, 400 mL/min/m² was the nadir DO_{2i} to reduce CS-AKI risk. The lack of correlation for STAT 1-3 neonates and STAT 4-5 infants could be "due to lack of effect or to the relatively small sample size of these two subgroups".[4]

There is a divide in the outcomes of these analyses. Two found a nadir DO_{2i} in the 250 and 280 mL/min/m2 range, comparable to the accepted GDP goal in adults.[6,15] The other three found significantly higher nadir DO_{2i} values between 340-400 mL/min/m².[4,8,16] Two more relevant studies are summarized below. Although neither examines the direct correlation between AKI and nadir DO_{2i}, both analyze factors related to preventing anaerobic metabolism on CPB and preventing CS-AKI.

- A study by Bojan et al. from 2020 examined the relationship between nadir DO_{2i} and lactate less than 2.5 mM/L after cross-clamp removal to determine the cut-off for aerobic metabolism. In a retrospective analysis of 180 neonates, the threshold to maintain aerobic metabolism at 37°C was 340 mL/min/m². Potential confounding factors in lactate levels include lactate from blood transfusions, aorto-pulmonary collaterals, and hyperglycemia.[1]
- A retrospective observational study of 235 patients undergoing a repair of congenital heart disease compared two perfusion strategies. One group had a goal hematocrit greater than 28% with a target cardiac index of 2.4 L/min/m², which is an estimated DO_{2i} of 306 mL/min/m², assuming a P_aO_2 of 200 mmHg. The other group had a goal hematocrit greater than 25% with a target cardiac index of 3.0 L/min/m², which is an estimated DO_{2i} of 341 mL/min/m². The group with the higher flow and lower hematocrit goals had a lower rate of any stage of AKI development. In addition, DO_{2i} values in the higher flow and lower hematocrit goals were significantly higher.[12]

The Bojan et al. and Reagor et al. studies' outcomes indicate that a threshold DO_{2i} of 340 mL/min/m² is a reasonable goal for pediatric patients. As the Reagor et al. publication discussed, an adequate DO_{2i} can be accomplished by managing hematocrit, flow rate, or both. In addition to GDP with an oxygen delivery goal, consideration should be given to the hematocrit and flow rate goals. Blood conservation is a goal in many surgical programs. Blood product administration has associations with various postoperative complications, including days of mechanical ventilation, thrombotic complications, and mortality.[3] Teams must determine a balance between hematocrit and flow rate. Flow rates can vary based on cannulation strategies and surgeon preference. Blood product administration varies by team based on surgeons, perfusionists, and anesthesiologist consensus. In addition to setting overall goals, patient-specific management remains crucial.

With the widespread adoption of in-line monitoring devices during CPB, perfusionists often have continuous trending data between running blood gases. The Terumo CDI 550 has the following options for variables to display: pH, pCO_2, pO_2, K^+, temperature, oxygen saturation, hematocrit, hemoglobin, oxygen consumption (actual or indexed), oxygen delivery (actual or indexed), base excess, HCO_3^-, and blood flow.[14] Blood flow is a variable input by the perfusionist and must be changed manually as the flow rate changes to maintain accurate calculated values. The Spectrum Quantum heart-lung machine has options to provide a continuous estimate or calculation of the following values: pO_2, pCO_2, F_iO_2, F_iCO_2, sweep rate, F_eCO_2, F_eO_2, oxygen saturation, hemoglobin, hematocrit, oxygen delivery (actual or indexed), oxygen consumption (actual or indexed), O_2 extraction ratio, and CO_2 production (actual or indexed).[13] The Quantum provides more real-time data because the blood flow rate and sweep gases can be measured continuously. Using trending devices combined with appropriate patient monitoring, GDP can become an added patient management tool.

Conclusion

Current publications related to pediatric GDP reveal a significant relationship between DO_{2i} and CS-AKI, which indicates clinical

INDIVIDUALIZED TREATMENT IS STILL THE PRIORITY BECAUSE THE CURRENT EVIDENCE DOES NOT DIFFERENTIATE BETWEEN PATIENT GROUPS.

relevance and warrants further study. Possible thresholds for nadir DO_{2i} from current data include 280, 350, and 400 mL/min/m^2.[4,6,8,15,16] These values provide a starting point for integrating GDP into pediatric perfusion practice. Incorporating other patient parameters like NIRS, S_vO_2, and lactate in combination with DO_{2i} provides a more thorough assessment of adequate perfusion. Individualized treatment is still the priority because the current evidence does not differentiate between patient groups. More research is needed to assess goals based on age range, cyanotic or acyanotic defect, and temperature. There is some evidence that a higher flow rate reduces the occurrence of CS-AKI, but more study is needed on flow rates and pressure goals as well. Another important area to consider is the mechanism of CS-AKI to determine other interventions to reduce kidney injury. One small study from 2017 by Lannemyr et al. measured hemodynamics using renal vein catheters in 18 patients undergoing CPB. Despite adequate systemic oxygen delivery, renal oxygen delivery was reduced due to renal vasoconstriction and hemodilution[9]. Further understanding the mechanisms behind renal oxygenation and hemodynamics on bypass will improve interventions to decrease kidney injury due to CPB.

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Molly O'Brien graduated from Miami University in 2019 with a BSE in Bioengineering and graduated from the Medical University of South Carolina with an MS in Cardiovascular Perfusion in 2021. Prior to her current job in pediatric and congenital perfusion at Cincinnati Children's Hospital, she worked at Montefiore Medical Center.

SPECIAL PROCEDURES

Amanda Crosby, Nick Mellas, Luc Puis

Cardiovascular Perfusion is a dynamic profession. Even in the face of staffing shortages, the perfusionist is faced with doing more with less and is required to perform at high competency levels in the operating room, intensive care setting, and elsewhere within the institution.

Today's cardiac surgery patient is often older, sicker, and requiring more complex operations. Education and training are important in providing care to these patients. The AmSECT Scope of Practice covers procedures that a perfusionist might perform. The profession constantly evolves, with new techniques and equipment to provide special procedures and care, and the Scope is revised to reflect the evolution.

Today's perfusionists may be called upon to develop procedures and techniques for services not commonly associated with our profession. Knowledge and understanding of special procedures are imperative to service a growing patient population with needs that are suited to being met with the perfusionist skill set. Staffing and equipment can be critical aspects in preparing for these special procedures.

Consider your practice and your level of involvement or capability to support the following special procedures.

- **Catheter thrombus extraction:** Removal of thrombus, typically in the venous system, through the use of a large funnel-tipped cannula. A simple circuit that utilizes negative pressure pulls the thrombus into a filter, and then the blood is returned, typically without an oxygenator inline.
- **ECMO:** Provides oxygenation support (VV) or oxygenation and cardiac support (VA) for profoundly sick patients. Even if your hospital doesn't have perfusionists provide the bedside care of the circuit and patient, having the knowledge base to deploy a circuit, troubleshoot, and consult on patients is very important. Another support variation is extracorporeal cardiopulmonary resuscitation (eCPR) which initiates ECMO as a salvage procedure on patients with cardiac arrest; it can be initiated in the ER or the field.
- **Extracorporeal carbon dioxide removal (ECCO2R):** Utilized on patients with severe hypercapnia; circuit focuses primarily on removing CO_2, not oxygenation.
- **HIPEC:** Circulation of hyperthermic chemotherapy to the abdomen cavity. The circuit is simple, with a reservoir, arterial pump, and heater device.
- **Liver Bypass:** Allows for continued venous blood circulation while excluding the liver during surgery, often used in Liver Transplants.
- **Lung transplantation:** Cardiopulmonary bypass or ECMO can be used to support the patient while undergoing a lung transplant.

- **TAVR:** Less-invasive repair of aortic valve insufficiency or stenosis, often in patients too sick for traditional, open aortic valve surgery. Perfusion should be prepared to assist in these cases if an emergency occurs.
- **IABP:** Counter pulsation device that provides increased blood flow to the patient during diastole and decreases the heart's workload. Requires dedicated machine, catheter-based approach, does not require heparin. Perfusion's level of involvement will vary by institution, potentially requiring their presence for insertion, operation, and troubleshooting.
- **TEG:** This lab demonstrates the functionality of the patient's coagulation system. Interpreting the thromboelastograph results may be necessary if recommending treatment through blood product usage.
- **VADs and Artificial Support:** Setup and insertion are critical. Recognizing and troubleshooting issues is where a clinician can be an asset to the institution. VADs may be temporary or long-term and may be inserted via a catheter or through open surgery.
- **Right heart support:** Single venous cannulation with a dual lumen catheter that provides support through a pump head; oxygenator is optional depending on patient pulmonary status.
- **Organ procurement (donation after circulatory death):** Supplies continued tissue and organ perfusion by extracorporeal circulation to enable the harvesting of organs after cardiac death.
  - **Normothermic Regional Perfusion (NRP):** Organ preservation technique that works to provide oxygenated blood flow and prevent ischemia
- **Autologous blood donation:** Blood is removed from the patient to spare the platelets and clotting factors from activation by exposure to the bypass circuit. The technique for removal and amount of blood taken vary by institutional protocols, but the principle is the same. Donation may be done by Perfusion immediately prior to bypass or by Anesthesia before incision.
- **Cell salvage:** The patient's whole blood is suctioned from the field, washed of debris, platelets, and clotting factors, and returned as concentrated red blood cells (RBCs).

This list is not meant to be comprehensive — but rather stimulate you to consider techniques of the Perfusionist possibly new to you. For more information on special patients, see the AmSECT Clinical Protocols page to learn more about different diseases, and for a template you can tailor to your institution.

The AmSECT Scope of Practice is currently being updated. If you have any practices from your institution that you'd like to see added or would like to provide comments, please reach out to ICEBP@amsect.org.

KNOWLEDGE AND UNDERSTANDING OF SPECIAL PROCEDURES ARE IMPERATIVE TO SERVICE A GROWING PATIENT POPULATION WITH NEEDS THAT ARE SUITED TO BEING MET WITH THE PERFUSIONIST SKILL SET.

Amanda Crosby, MS, CCP

Nick Mellas, RRT CCP LP

Luc Puis, ECCP

EYEWITNESS TO HISTORY

Mark Kurusz, CCP and Kelly D. Hedlund, MS, CCP

Photograph taken May 6, 1953 by Dr. George Haupt. (Courtesy Thomas Jefferson University, Scott Memorial Library, and Mr. F. Michael Angelo, Archivist)

Virtually all clinical perfusionists are familiar with the story of the first successful use of a heart-lung machine on May 6, 1953. The closure of an atrial septal defect by Dr. John H. Gibbon, Jr. in an 18-year-old college student, Cecelia Bavolek, has been frequently described — in multiple publications, book chapters, interviews, presentations, and even on the Internet. Many more people than those named in these recountings were crowded into the room that fateful day because this was the second clinical case in which the Gibbon-IBM Model 2 was to be used after hundreds of animal experiments. A previous case a year earlier in a child had resulted in the patient's death from a mistaken diagnosis — but the machine had performed perfectly. So, who were some of those in the Operating Room during the historic case? What did they do that day, and what became of them after 1953?

Miss Joanne Crothers was a 24-year-old laboratory technician who had gone to work in Dr. Gibbon's laboratory in 1947, right after graduating high school. She scrubbed in on cases, assisted during benchtop experiments, cleaned and sterilized the machine between uses, and became familiar with operating the Gibbon-IBM heart-lung machines (Models 1 and 2). The evening before the case on May 6, she helped push the huge console from the eighth-floor animal laboratory down to the fourth-floor main operating suite; it weighed approximately one ton, and she recalled the elevator floor dropping a few inches when the machine was pushed inside. Joanne was responsible for priming the machine early on the morning of surgery, first with saline and then by adding several units of freshly drawn human blood. Once a film had been established on screens encased in the clear plastic oxygenator, recirculation was necessary to maintain the film for gas exchange when the patient was connected to the system. The recirculation rate was 4 L/min, and it had been started early in the morning, well before the patient had even been put to sleep and six hours before the pump was used; high flow recirculation was maintained the entire time. Joanne would later recount that after the case, she tip-toed up to the ward to see how Cecelia was doing during her recovery. Later that summer, Joanne married a music professor and moved to Bloomington, Indiana. Her obituary from 2021 noted she had been the perfusionist during the historic case.

Dr. Frank F. Allbritten, Jr. was the first assistant surgeon. When serious problems arose during perfusion because clotting had developed in the oxygenator and the roller pumps automatically shut down due to high pressures and a low reservoir level, he advised Dr. Gibbon to abandon the plan to use a pericardial patch to close the large septal defect and instead close it directly with running silk suture. In 1954, Dr. Allbritten moved to Kansas City, where he was appointed Professor and Chairman at the University of Kansas Medical Center. His career focused on lung and chest diseases, and he wrote chapters for the 1962 and 1969 editions of Gibbon's textbook, *Surgery of the Chest.* He retired in 1972.[1]

Dr. Bernard J. Miller, having completed his surgical residency in 1950 under Dr. Gibbon's preceptorship, was the second assistant surgeon during the case. As a Research Associate in Dr. Gibbon's laboratory (1950-54), he developed surgical procedures to close septal defects and worked closely with IBM engineers to perfect the Model 2 for clinical use. Miller also invented a negative pressure end-expiratory ventilator that greatly improved animal results; this device later became known as the "Jefferson Ventilator."[2] On May 6, when a crisis arose with the perfusion circuit, Dr. Gibbon pleaded with Dr. Miller to deal with the problem that had shut down all pumps.[3] He broke scrub, bypassed the recirculation pump, quickly added the remaining donor blood and crystalloid solution to the circuit, and hand-cranked the systemic pump to correct patient hypovolemia. He later admitted a catastrophe had been narrowly avoided. Unfortunately, there was a terrible falling out with Dr. Gibbon in 1954. Dr. Miller left the program but became a successful thoracic, vascular, and oncologic surgeon at Germantown Hospital in Philadelphia. He pioneered the use of extracorporeal chemoperfusion for inoperable malignant tumors[4] and was issued several patents for his work with extracorporeal circulation. He maintained a faculty position in the Department of Anatomy and was later recognized by Jefferson University for his "distinguished service in teaching and work on the heart-lung machine." In 1996, he was honored as that year's recipient of the Holley Award given by the American Society of Mechanical Engineers.

Others[5] present included **Dr. Thomas F. Nealon, Jr.**, the fourth surgeon scrubbed in during the case. Despite the desperate problems during perfusion with hypoxia, low blood pressure, acidosis, and lack of perfusion for approximately 20 minutes, Dr. Nealon's progress notes on the evening after surgery reported the patient was lucid and making adequate urine. After completing his residency, he stayed at Jefferson as a close colleague of Dr. Gibbon, eventually becoming a Professor of Surgery; in 1968, he moved to New York, where he was appointed Chairman of the Department of Surgery at St. Vincent's Medical Center. During his career, Dr. Nealon edited two textbooks on cancer management and fundamentals in surgery. In 1950, **Dr. Thomas L. Stokes** was active in the research laboratory, performing important studies on the screen oxygenator concept as it was being developed.[6] **Dr. John J. McKeown, Jr.** was a surgical resident at Jefferson on May 6 and subsequently became a Research Associate to continue studies on extracorporeal circulation at Jefferson; in 1959, he was appointed Chief of Thoracic Surgery at Philadelphia General Hospital. Both Drs. Stokes and McKeown also wrote progress notes in the patient's chart. **Dr. Robert K. Finley, Jr.** was the one who placed a Cournand needle in the patient's right brachial artery, which was connected directly to a mercury manometer. As a scribe for Dr. Gibbon, he penned a brief operative note at the conclusion of surgery. In 1956, he moved to Ohio and practiced surgery for more than 30 years while mentoring scores of medical students. **Dr. George J. Haupt,** another surgical resident, observed the case and took the famous photo during the operation (see Fig. 1). **Dr. Anthony R.C. Dobell** was a junior resident tasked with checking on the patient every two hours during her immediate postoperative period. Amusingly, in the years leading up to the first successful case, Dr. Dobell would occasionally sneak across town to Hahnemann Hospital to watch Dr. Charles Bailey operate. Known to many as the "Philadelphia Maverick," Bailey was doing much more surgery than Gibbon at the time. Dr. Dobell later studied coagulation with Dr. Gibbon and, in 1956, became Chief of Cardiac Surgery at the Royal Victoria Hospital in Montreal. **Dr. Victor F. Greco,** also a surgical resident, had a memorable role during the case: he was assigned to work with Miss Crothers to operate the heart-lung machine. When clotting developed in the oxygenator, pressures got so high from the continuously rotating recirculation pump that blood began leaking from the housing, and he had to get up on a stool to hold the plastic lid in place for fear it would rupture. After his residency, he moved to Hazelton, Pennsylvania, ultimately becoming Deputy Secretary of

Health, Chairman of the State Board of Medicine, and President and Trustee of the Pennsylvania State Medical Society. At one time, he was the personal physician to Muhammad Ali when the champ had a training camp in rural Pennsylvania. After a two-year moratorium on cardiac surgery, which Dr. Gibbon had declared in the summer of 1953, **Dr. John Y. Templeton, III,** who was also a surgical resident, witnessed the historic case on May 6 and took over clinical duties to establish a busy cardiac surgery service at Jefferson using the third iteration Gibbon-IBM (Model 3) heart-lung machine; this system was partially constructed with disassembled parts from the Model 2 that had been used on May 6. In 1967, he succeeded Dr. Gibbon as the Samuel D. Gross Professor and Chairman of Surgery at Jefferson.

Miss Kitty Rowlands was a nurse anesthetist for all of Dr. Gibbon's cases in the 1950s; in the early days at Jefferson, no anesthesiologists were on staff. Her notes during the May 6 operation became part of the official record, including question marks when the patient's blood pressure was unmeasurable. She died of cancer sometime before a 30th anniversary gathering in 1983 to commemorate the case. Another key figure in the room that day was **Mrs. Mary (Maly) Gibbon**, who had worked tirelessly with her husband in the animal laboratory two decades earlier when the heart-lung machine was being developed for anticipated pulmonary embolectomy surgery. On May 6, she sat in the corner of the Operating Room, taking notes of events, including times and details of the perfusion that later were typed up as the official record of the case. Maly attended some early AmSECT conferences and, in 1974, enthusiastically bestowed the first Gibbon Award to Dr. Clarence Dennis.

After his retirement in 1967, Dr. Gibbon was an avid tennis player, wrote poetry (which had been his avocation during his college years), traveled widely recounting the historic case, and was inspired to take up painting after the influence of Maly's father.[7] He suffered a fatal myocardial infarction on the tennis court in 1973. He had dismissed the urgings of his good friend, Dr. Harris B. Shumacker, to have a cardiac catheterization and possible coronary artery bypass operation.[8]

What became of the patient, **Cecelia Bavolek**? She recovered from her surgery and was discharged on postoperative day 13. A cardiac catheterization a few weeks later confirmed the septal defect remained closed. She resumed normal physical activities, and in 1963, she was named Heart Fund Queen by the American Heart Association and met then-Vice President Lyndon B. Johnson. The notoriety surrounding her historic operation led her to withdraw from the public and not grant any interviews, especially after someone suggested she could be in a circus freak show and another person made a stupid comment that Cecelia had been cut in half during the operation. She graduated from the University of Pennsylvania and the Wharton School of Business and became an administrative assistant at Hahnemann College.[9] Cecelia died in 2000, having lived 65 years, which was considered an impossibility by the physicians caring for her in the months preceding her operation in 1953. As a footnote, once the diagnosis had been made and surgery was her only hope, she was offered the option of hypothermia with inflow occlusion for closure of the defect. She said she could not stand the thought of being frozen, so she opted for Dr. Gibbon's machine and lots of prayers.

In closing, all the individuals named above have passed, but their time spent at Jefferson, particularly during the historic case of May 6, remained one of the highlights in their productive lives, as noted during interviews, publications, and obituaries.

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Mark Kurusz, CCP

Kelly D. Hedlund, MS, CCP

SELF QUIZ Q4 2023

By Shannon Barletti, BSN RN CCRN CCP, and Michelle Jaskula-Dybka, MS CCP

1. Dopamine:

- **a.** Mechanism of action is DA1 and DA2, beta receptor effects and alpha adrenergic at higher doses
- **b.** Is the immediate precursor for norepinephrine
- **c.** Decreases GI activity
- **d.** All of the above

2. The cardiovascular effects of dopamine are:

- **a.** Positive inotropic effect secondary to effects on beta 1 receptor
- **b.** Increase in systolic blood pressure
- **c.** Both A and B
- **d.** None of the above

3. Norepinephrine:

- **a.** Mechanism of action is alpha and beta adrenergic receptor activity and is stored in synaptic cleft of neurons
- **b.** Precursor to epinephrine
- **c.** Only A
- **d.** Both A and B

4. The cardiovascular effects of norepinephrine are:

- **a.** Increase in systolic blood pressure and diastolic blood pressure, no change in cardiac output, and increased SVR
- **b.** Tachycardia
- **c.** Increases splanchnic and hepatic blood flow
- **d.** None of the above

5. Which of the following is a potassium sparing diuretic?

- **a.** Amiloride
- **b.** Bumetanide
- **c.** Spironolactone
- **d.** A and C

6. Which of these is a calcium channel blocker that is particularly selective for cerebral and coronary vessels?

- **a.** Verapamil
- **b.** Nicardipine
- **c.** Diltiazem
- **d.** Amlodipine

7. Veno-venous bypass for a liver transplant involves cannulation of ___________, ___________, and ___________.

8. Malignant hyperthermia can be triggered by ___________ as well as ___________.

9. Which of the following is true about malignant hyperthermia?

- **a.** Calcium is released in a continuous fashion from the sarcoplasmic reticulum in skeletal muscle leading to continuous contraction and activation of calcium-ATPase
- **b.** Continuous muscle contraction leads to depletion of ATP stores and a hypermetabolic state causing hypercarbia, respiratory acidosis, and heat production
- **c.** Oxygen stores become depleted leading to anaerobic metabolism
- **d.** One of the triggers is a neuromuscular blocking agent
- **e.** All of the above

10. During pregnancy, which trimester is ideal timing to perform cardiopulmonary bypass surgery?

- **a.** First trimester
- **b.** Second trimester
- **c.** Third trimester
- **d.** Any trimester

11. True or False. Heparin does not cross the placental barrier.

a. True **b.** False

12. ___________ has shown to cause decreased uterine blood flow and releases free cyanide leading to metabolic acidosi

13. The Impella controller automatically adjusts the purge flow between ___________, and ___________mL/hr to maintain the purge pressure between ___________, and ___________.

- **a.** 2-30mL/hr, 300-1100mmHg
- **b.** 50-100mL/hr, 150-500mmHg
- **c.** 2-30mL/hr, 150-500mmHg
- **d.** 50-100mL/hr, 300-1100mmHg

14. What steps should the perfusionist take if the Impella purge pressure high alarm occurs:

- **a.** Assess tubing for kinks
- **b.** Assess for leaks or loose connections
- **c.** Assess purge sidearm to ensure it is straight
- **d.** Both A and C

15. If the Impella device is left across the aortic valve while cross clamped, what steps should the perfusionist take?

a. Turn the Impella controller off

b. Remove the Impella plug from the controller

c. Turn the Impella P-Level to P2

d. Turn the Impella P-Level to P0 and activate surgical mode on the AIC

16. What does putting the Impella AIC in surgical mode do?

a. Silences the Impella stopped alarm

b. Stops the Impella motor and the Impella purge

c. Allows the purge to be maintained and silences the Impella stopped alarm when the P-Level is reduced to P-0

d. None of the above

17. What are the max flows on the Impella RP device with SmartAssist?

a. > 4LPM

b. > 5LPM

c. 6.0 LPM

d. > 6LPM

For questions 18–22, please read/refer to the following article:

Bartoli CR. Pathologic von Willebrand factor degradation is a major contributor to left ventricular assist device-associated bleeding: pathophysiology and evolving clinical management. *Ann Cardiothorac Surg*. 2021 May;10(3):389-392. doi: 10.21037/acs-2020-cfmcs-29. PMID: 34159121; PMCID: PMC8185388.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8185388/

18. ___________is the number one cause of hospital readmission for ambulatory LVAD patients.

a. Infection

b. Pump thrombosis

c. Gastrointestinal bleeding

d. Congestive heart failure

19. Normal intravascular shear stress is___________.

a. 1 – 5 Pa

b. 2 – 8 Pa

c. 8 – 12 Pa

d. 10 – 15 Pa

20. VonWillebrand factor activation occurs above ___________.

a. 5 Pa

b. 10 Pa

c. 15 Pa

d. 20 Pa

21. True or False. Supraphysiologic LVAD shear stress causes VWF degradation by activating VWF and exposing ADAMTS-13 cleavage sites for enzymatic degradation.

a. True **b.** False

22. Within ___________ of LVAD support, pathologic VWF degradation occurs and within ___________, VWF deficiency plateaus and remains until LVAD support is discontinued.

a. Hours, 30 days

b. 72 hours, 90 days

c. Minutes, 24 hours

d. 24 hours, 1 week

References:

1. Abiomed Academy: https://www.heartrecovery.com/education

2. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8185388/

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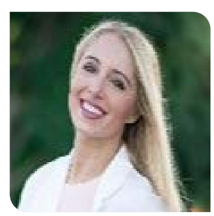
Shannon Barletti, *BSN RN CCRN CCP*



Michelle Jaskula-Dybka, *MS CCP*

1. D **2.** C **3.** D **4.** A **5.** D **6.** B **7.** PORTAL VEIN, INFERIOR VENA CAVA, INTERNAL JUGULAR VEIN **8.** POTENT INHALATION ANESTHETICS SUCH AS ISOFLURANE AND SEVOFLURANE, SUCCINYLCHOLINE **9.** E **10.** B **11.** TRUE **12.** NITROPRUSSIDE **13.** A **14.** D **15.** D **16.** C **17.** A **18.** C **19.** B 20. B **21.** TRUE **22.** C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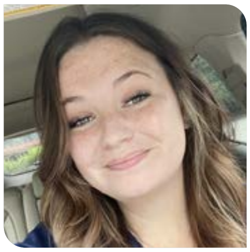
Meet the 2024 Mary Hartley Scholarship Winners!



McKenzie Ayala

Jennifer Stubblebine

What does receiving the scholarship mean to you?

MCKENZIE: I am honored and humbled to be selected as the recipient of this scholarship. As I continue through my second year of perfusion school and begin my career, I will continue to show the same passion, dedication, and hard work towards the field of perfusion!

JENNY: During my educational journey, I have been fortunate to receive the support and encouragement of my friends and family. Likewise, this represents the support and encouragement that the Perfusion Community has for students and future Perfusionists. While our community is small, it offers a level of support that is unrivaled. Thank you to AmSECT, Mary Hartley, and the community that has made this scholarship possible!

How did the scholarship impact your efforts/What did the scholarship enable you to do?

MCKENZIE: Receiving this scholarship helps take the some of the stress away while I am completing clinical rotations and taking classes online.

JENNY: My family has been incredibly supportive as I have pursued my career ambition. All of them have contributed in one way or another. This award will help to lessen some of the financial burden as I begin my new career.

Additional information you'd like to share.
MCKENZIE: I am completing my clinical rotations at Strong Memorial Hospital (Univeristy of Rochester), Emory University, Piedmont Atlanta, and Children's Healthcare of Atlanta. Prior to perfusion school, I worked as a nurse in the CVICU at Piedmont Atlanta.

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Questions? Please contact AmSECT Headquarters at amsect@amsect.org.

Meet Your AmSECT Staff

The team looks forward to building a strong relationship with AmSECT leaders, volunteers, members and supporters!

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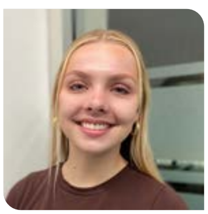

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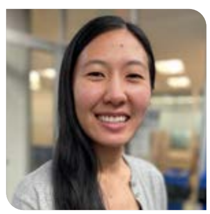

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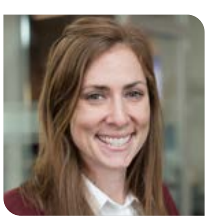

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AmSECT

AmSECToday Survey

AmSECT's task force for the *Your Opinion Matters* campaign, along with the Board of Directors (BOD), is launching a series of surveys geared toward obtaining feedback from our membership. The BOD wants to hear from you on each of these surveys so that we can best align and deliver what is important to you. Our membership is the most integral part of who we are and is our top priority. Your participation will be important in this campaign, so please take a few minutes of your time to provide us with your valuable feedback.

Each of these surveys will be sent to you via email communication quarterly. The first in this series is regarding this publication, AmSECToday, and others will follow. We appreciate your participation and most importantly appreciate your commitment to your profession. AmSECT is what it is today because of its membership. Thank you in advance for your participation and continuous support.

Please participate in our first survey below.

Take the Survey