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Original Articles

International Pediatric Perfusion Practice: 2011 Survey Results

Brian Harvey, CCP;* Kenneth G. Shann, CCP;* David Fitzgerald, CCP;† Brian Mejak, CCP;‡ Donald S. Likosky, PhD;§ Luc Puis, ECCP;‖ Robert A. Baker, PhD, CCP(Aust);¶ Robert C. Groom, MS, CCP** for the American Society of ExtraCorporeal Technology's International Consortium for Evidence-Based Perfusion and Pediatric Perfusion Committee

**Montefiore Medical Center, Bronx, New York; †Inova Fairfax Hospital, Falls Church, Virginia; ‡Children's Hospital Colorado, Aurora, Colorado; §University of Michigan Medical School, Ann Arbor, Michigan; ‖University Hospital Brussels, Jette Brussels, Belgium; ¶Flinders Medical Centre, Bedford Park, South Australia, Australia, and Flinders University, Bedford Park, South Australia, Australia; **Maine Medical Center, Portland, Maine*

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Abstract: New cardiopulmonary bypass devices and new innovative methods are frequently reported in the literature; however, the actual extent to which they are adopted into clinical practice is not well known. We distributed an electronic survey to 289 domestic and international pediatric congenital surgery centers in an effort to measure attributes of current clinical practice. The survey consisted of 107 questions relating to program demographics, equipment, and techniques. Responses were received from 146 (51%) of queried centers and were stratified into five distinct geographic regions (North America, Central and South America, Oceana, Europe, and Asia). Most of the responding centers reported use of hard shell venous reservoirs. Closed venous systems were used at 50% of reporting centers in Central and South America as compared with only 3% in North America and 10% in Asia. Seventy-one percent of the programs used some form of modified ultrafiltration. Use of an arterial bubble detection system varied between 50% use (Central and South America) vs. 100% (North America and Oceana). "Del Nido" cardioplegia is more common in North America (32%) than any other continent, whereas Custodial® HTK solution is much more prevalent in Europe (31%). Wide variation in practice was evident across geographic regions, suggesting opportunities for further investigation and improvement.
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The conduct of pediatric, infant, and neonatal cardiopulmonary bypass (CPB) is continuously evolving as new devices and techniques are reported. The extent to which particular new devices and innovative techniques are adopted into clinical practice is not well described. Regional surveys have been conducted that document practices in specific countries and geographic regions [United Kingdom (1), Japan (2), France (3), and North America (4–7)]. These surveys have documented variation in practice within regions and have provided a reference for cardiac teams; however, a contemporary global perspective has been lacking.

Two committees within the American Society of Extracorporeal Technology, The International Consortium for Evidence-Based Perfusion, and The Pediatric Perfusion Committee conducted a worldwide, web-based survey of cardiac programs performing congenital heart surgery. The goal of the survey was to document the current clinical practice, including program demographics, equipment, and techniques across five intercontinental regions of the world.

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Address correspondence to: Robert C. Groom, MS, CCP, Cardiovascular Surgery, ME Medical Center, 22 Bramhall Street, Portland, ME 04102. E-mail: groomr@mmc.org
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MATERIALS AND METHODS

The survey questionnaire previously used in 2005 by Groom and colleagues (7) was reviewed and updated.

The survey was translated into Spanish, French, Portuguese, and Japanese and imported into SurveyMonkey™ (Palo Alto, CA). The survey and invitation e-mail were piloted to 10 perfusionists from representative regions (Canada, Japan, Australia, New Zealand, Belgium, Brazil, North America, and France). Included with the pilot materials was an evaluation form, developed in Microsoft Excel® (Microsoft Corporation, Redmond, WA), allowing structured feedback regarding the clarity and appropriateness of each survey question. On completion of the pilot, the evaluation forms were reviewed and the survey was amended accordingly. Sixteen perfusionists were invited to be regional leaders (see Acknowledgments) to assist in developing a complete list of active programs and to encourage local participation. Because the unit of analysis was by cardiac center, a survey was sent to chief/lead perfusionists at each center.

A letter inviting participation was distributed by e-mail to 289 active programs from 34 different countries. The e-mailed letter contained web links to the survey in Spanish, French, Portuguese, Japanese, and English. Recipients were instructed to click on the link contained in the e-mail message to access the 107-question survey. The survey was delivered on December 10, 2010. Subsequent e-mail invitations were sent to nonresponding and incomplete-responding centers every month thereafter through April 2011 with responses accepted through May 6, 2011. On completion, the collated results were exported from SurveyMonkey™ as an Excel® spreadsheet for analysis.

Responses were stratified into one of the following geographic regions; North America (NA), Central America and South America (CSA), Asia, Europe (EU), and Oceana (including Australia and New Zealand) (OA). The results were tabulated as proportions for categorical variables and as median for continuous variables and stratified by geographic area or percentage of total respondents. Questions relating to technique and equipment were reported as frequency relative to the number of total responding centers and evaluated accordingly.

RESULTS

Program Demographics

Responses were received from 146 of the 289 centers for an overall response rate of 51%. Responses were received from 22 (65%) of the 34 surveyed countries. The response rates for the five geographic regions are summarized in Table 1. The mean annual pediatric caseload for responding centers in 2010 was 202 cases/year per center (median 160 cases/year per center; range, three to 735 cases/year per center). Total reported pediatric case count in 2008, 2009, and 2010 (estimate) was 28,344, 29,196, and 29,650, respectively.

Table 1. Surveyed regions and response rate.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Regional response rate	82	23	29	100	35	51
Percent of total responses	61	10	7	3	19	100

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 2 summarizes the staffing level for cases by region. The majority of centers responding from Asia and OA reported that they staffed each pediatric case with two perfusionists. Seventy-eight percent of respondents believed that 50 cases/year was the minimum number of annual cases one should perform to be qualified as a competent pediatric perfusionist.

Equipment

Table 3 shows the percent of centers that uses various safety devices and circuit components stratified by geographic region. The use of a level detector was reported by 100% of responding centers. The majority of centers reported using bubble detectors exclusive of CSA, where only 50% of centers reported using them. Gas supply oxygen analyzers were used by only 40% of centers from NA as compared with 100% of centers responding from Asia. Prebypass filters were used more frequently in centers responding from OA and NA, as compared with centers responding from EU, Asia, and CSA, respectively. There was a significantly lower rate of vent/sucker line one-way valves reported by centers within CSA than centers from all other responding regions. Closed venous reservoir systems were reportedly used by 10% of all responding centers and the majority were reportedly used by centers in CSA. Surface modifications, or circuit coatings, were used in 85% of the responding centers. Ten percent of responding centers reported not using any type of surface coating on their pediatric circuit. The use of vacuum-assisted venous drainage (VAVD) was

Table 2. Number of perfusionists present for a pediatric/neonatal case by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
One	33	38	0	0	50	33
Two	43	38	89	80	12	41
1+ backup	25	23	11	20	38	26

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 3. Safety devices and circuit components by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Safety devices						
Level detector	100	100	100	100	100	100
Bubble detector	96	50	70	100	79	86
One-way valve in vent line	87	7	90	40	57	72
One-way purge line	85	79	100	100	86	86
Gas supply oxygen analyzer	40	50	100	60	75	53
Arterial pump						
Roller	66	36	50	100	71	64
Centrifugal	8	7	0	0	0	5
Roller and centrifugal	26	57	50	0	29	30
Components/techniques						
Open reservoir–hard shell	97	50	90	100	89	90
Vacuum assist venous drainage	74	21	60	40	54	63
Prebypass filter	82	36	30	100	29	64
Arterial line filter–neonates	94	86	100	100	79	91
Arterial line filter–infants	96	86	100	100	82	92
Arterial line filter–pediatrics	93	93	100	100	89	93
Cardioplegia filter	36	23	33	80	19	33
Ultrafiltration device use						
Ultrafiltration used <50% of cases	2	31	0	0	27	10
Ultrafiltration used 50–89% of cases	6	23	0	20	23	11
Ultrafiltration used >90% of cases	91	46	100	80	50	79

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

predominantly reported by centers within NA (74%) as compared with 21% in CSA. Only 5% of all responding centers reported the exclusive use of centrifugal arterial pumps for pediatric CPB as compared with 64% of all responding centers that reported the exclusive use of roller pumps, and 30% reported some use of each type of pump. For pediatric procedures, 93% of responding centers reported the use of an arterial filter. For neonates and infants, 92% reported the use of an arterial filter. Of those centers using an arterial line filter, 23% used a filter that was integrated with the oxygenator.

Monitoring Devices

Table 4 depicts the reported use of continuous real-time monitoring devices during CPB including blood gas monitoring and cerebral oximetry. Cerebral saturation monitoring was reported in 84% and 90% of responding centers from NA and Asia, respectively, whereas 0% of centers in CSA reported use. Most centers (other than CSA) used continuous in-line arterial blood gas monitoring. Continuous in-line venous blood gas monitoring was used by 26% of all responding centers and in-line venous saturation sensors by 86% of responding centers.

Table 4. Real-time monitoring during CPB by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Electroencephalogram	4	7	20	0	4	5
Arterial pressure by cuff	53	21	80	0	39	47
Arterial pressure by catheter	89	100	100	100	86	90
Pulmonary artery pressure	38	50	40	0	54	41
Left atrial pressure	38	36	50	20	54	41
Central venous pressure	87	100	80	100	100	90
CPB arterial line pressure	94	64	100	80	96	92
Cardioplegia infusion pressure	96	57	90	100	93	91
Pulse oximetry	87	93	90	100	93	89
Cerebral oximetry	84	0	90	40	79	74
Electronic medical record	35	8	56	100	73	43
Arterial blood gas–in-line	83	50	90	100	93	83
Venous blood gas–in-line	25	21	40	0	32	26
Venous saturation–in-line	90	43	100	80	89	86
Other	8	7	0	20	11	8

CPB, cardiopulmonary bypass; NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 5. Extracorporeal support use by region.*

Type of Support	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
ECMO	93	36	100	100	100	90
Centrifugal pump VAD	57	43	90	80	71	62
Pneumatic VAD	34	0	0	40	50	32
Intra-aortic balloon pump	28	14	20	20	43	29
Roller pump	21	21	30	0	18	21
Other	12	7	0	0	11	11
Do not use VAD	4	36	10	20	0	8

*Percentages do not add up to 100%.
NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union; ECMO, extracorporeal membrane oxygenation; VAD, ventricular assist device.

Table 6. Type of oxygenator used for ECMO by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Silicone	8	22	0	0	4	7
Hollow fiber	9	22	40	0	7	12
Polymethylpentene with heparin coating	56	44	40	40	71	57
Polymethylpentene without heparin coating	22	4	4	11	11	20
Other	5	7	16	49	7	5

ECMO, extracorporeal membrane oxygenation; NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Only 43% of centers responding from CSA reported the use of in-line venous saturation sensors. The use of electronic medical recording (EMR) varied widely from only 8% in CSA to 100% in OA with 43% of all responding centers using EMR.

Ventricular Assist Devices

Ninety-two percent of centers reported they have at least one means of extracorporeal support available at their center (Table 5). The most common form of extracorporeal support was extracorporeal membrane oxygenation (ECMO). Thirty-four percent, 40%, and 50% of responding centers from NA, OA, and EU, respectively, use pneumatic ventricular assist devices (VADs). CSA and Asia report no use of pneumatic VADs. Seventy-six percent of all reported ECMO systems used the polymethylpentene oxygenator with 57% of those being heparin-coated (Table 6). Seventy-nine percent of all centers use a centrifugal pump in their ECMO circuit (Table 7).

Techniques

Circuit Prime and Blood Products: Typical CPB solutions and medications added to the perfusate are displayed in Table 8. Fifty-one percent of all responding centers reported the use of Plasma-Lyte® A (Baxter Corporation, Deerfield, IL) as the priming solution. In addition, 77% of all centers reported using 25% albumin in the circuit prime. Outside of NA, more than half of the centers responded "other crystalloid solution," which included: Ringer's acetate, Plasma-Lyte 148 (Baxter Corporation) NaCl .9%, NaCl .45%, hetastarch 6%, and Sublood-BS® (Fuso Pharmaceutical Industries Ltd., Osaka, Japan).

Ninety percent of centers in Asia reported they wash packed red blood cells before introducing them into the CPB circuit vs. NA (54%), CSA (21%), EU (18%). Overall approximately 39% of responding centers reported the use of retrograde autologous prime (RAP), exclusive of Asia, which does not report using RAP on pediatric patients. The average static prime volume (defined as the minimum operating level of the neonatal circuit including cardioplegia if blood cardioplegia is used) for a neonatal circuit across all of the geographic regions was 300 mL.

Ultrafiltration: Overall 86% of centers reported the routine use of ultrafiltration during CPB. There were several methods of ultrafiltration reported as shown in Table 9. Modified ultrafiltration was reported by 71% of centers (62% arterial venous-modified ultrafiltration and

Table 7. ECMO circuit–centrifugal pumps by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Centrifugal	71	60	90	100	96	79

ECMO, extracorporeal membrane oxygenation; NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 8. Prime and drug additives by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Crystalloid						
Plasma-Lyte A	70	7	10	60	29	51
Normosol-R	21	0	0	0	7	14
Lactated Ringer's	7	36	40	0	18	14
Other	2	57	50	40	46	21
Colloid						
5% albumin	10	14	10	0	25	13
25% albumin	89	71	90	80	36	77
Hetastarch	0	0	0	0	14	3
5% plasma protein	1	0	0	0	4	1
Pentastarch	0	0	0	20	4	1
Gelatin	0	14	0	0	18	5
Drug*						
Heparin	99	100	90	100	100	93
Sodium bicarbonate	96	93	70	80	64	87
Mannitol	79	93	80	20	75	77
Calcium chloride	34	36	0	60	7	27
Methylprednisone	25	21	0	0	4	18
Antibiotics	27	29	70	20	14	27
Furosemide	21	0	0	0	4	14
Dexamethasone	4	7	0	0	0	3
THAM	0	0	0	0	18	3
Lidocaine	1	0	0	0	0	1
AT-III	21	0	20	0	31	20
Aprotinin	4	15	11	20	8	7
Antifibrinolytics	94	92	22	100	73	85

*Percentage does not add up to 100%.
NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union; THAM, trome thamine; AT-III, antithrombin 3.

9% venovenous-modified ultrafiltration). Forty-seven percent of centers were using ultrafiltration before CPB to concentrate the CPB prime.

Myocardial Protection: The majority of reporting centers (68%) used a high-potassium depolarizing cardioplegic solution (Table 10). Thirty-two percent of centers use hyperpolarizing (Custodiol® HTK Solution [Dr. Franz Köhler Chemie GmbH, Alsbach-Hähnlein, Germany]) or modified depolarizing (Del Nido [Original patent University of Pittsburgh now expired; Composition (8)]) solutions for myocardial protection. "Del Nido" use was more common in NA (32%) than any other continent. Custodiol® HTK is more common in EU (31%) than other continents.

The most commonly used method of cardioplegia administration was the single-pass roller pump in a 4 parts blood:1 part crystalloid ratio (Table 11). In CSA, unlike any other continents, approximately 50 percent of centers reported the use of administration through a pressure bag. In addition, they had the highest rate of direct injection of cardioplegia with a syringe by the surgeon (14%). In OA, roller pumps were reported to be the exclusive means of cardioplegia delivery and of that, 80% reported a single-pass system and 20% a recirculating system (Table 12).

Vacuum-assisted Venous Drainage: The use of vacuum-assisted venous drainage (VAVD) was reported by 64% of responding centers. VAVD is most common in NA and least common in CSA.

Table 9. Types of ultrafiltration by region.*

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Never	1	14	10	0	4	3
Pre-CPB	51	36	60	100	25	47
A-V MUF	69	50	60	100	43	62
V-V MUF	8	14	20	0	7	9
Post-CPB	21	21	30	20	11	20
During CPB	89	79	80	100	79	86

*Percentage does not add up to 100%.
NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union; CPB, cardiopulmonary bypass; A-V MUF, arterial–venous modified ultrafiltration; V-V MUF, venous–venous modified ultrafiltration.

Patient Management

Heparin Management: The majority of responding centers (79%) administered additional heparin only if the

Table 10. Cardioplegia solutions used in 2010 by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Hyperpolarizing (Custodiol® HTK)*	4	23	0	0	31	10
Depolarizing (high potassium)	64	77	89	100	62	68
Modified depolarizing (del Nido)†	32	0	11	0	8	22

*Custodiol® HTK Solution (Dr. Franz Köhler Chemie GmbH, Alsbach-Hähnlein, Germany).
†Original patent University of Pittsburgh now expired. Composition (8).
NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

activated clotting time fell below the acceptable range. Centers in NA (19%) and EU (8%) administered additional heparin if the measured heparin level fell below the acceptable range.

Hypothermia Technique: Eighty-five percent of respondents reported they target a temperature of 18°C when performing low-flow perfusion in patients between 1 month and 18 years of age vs. 15% targeting a temperature of 16°C for deep hypothermic circulatory arrest (DHCA) in the same patient age groups. Thirty percent of respondents reported targeting a temperature of 15°C when performing DHCA in a patient population under the age of 1 month vs. 70% targeting a temperature of 19°C for low-flow perfusion in the same patient age group.

Blood Gas Management: For procedures involving hypothermia, 19% percent used alpha-stat, 31% used pH-stat, and 51% used a mixed management strategy (Table 13).

Hemodilution: The average minimal acceptable hematocrit during mild hypothermia was 26% (range, 17–35%; median, 28%). The average minimal acceptable hematocrit during deep hypothermia was 25% (range, 15–34%; median, 25%). For patients with cyanotic defects, the average minimal accepted hematocrit before separation from bypass was 33% (range, 10–48%; median, 35%). For patients with noncyanotic defects, the average minimal accepted hematocrit before termination of bypass was 29% (range, 8–48%; median, 30%).

DISCUSSION

A survey is simply an attempt to derive generalizations that describe a given population or subject area. The aim of this survey was to determine the current norm of clinical practice related to pediatric perfusion from both worldwide and regional perspectives. We found emerging trends and areas of regional variation that demonstrate the diffusion of innovation.

We tried to reduce the sampling-related error by endeavoring to survey every pediatric center. However, we were unable to determine a true denominator of pediatric centers given there is no single reliable list of worldwide programs. Engagement of regional leaders to aid us in identifying contacts at centers and to encourage participation at centers likely improved response rate. Multiple subsequent e-mail invitations sent to nonrespondents proved to

Table 11. Type of cardioplegia system by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Recirculating	24	23	44	20	27	25
Single pass	72	54	44	80	42	63
Syringe	1	15	0	0	15	5
Do not use	1	8	11	0	12	5
Other	3	0	0	0	4	2

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 12. Warm cardioplegia before cross-clamp removal by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Yes	14	8	22	20	4	12
No	77	62	56	60	92	76
Sometimes	10	31	22	20	4	12

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

Table 13. Blood gas management strategy during hypothermia by region.

	NA (n = 89) (%)	CSA (n = 14) (%)	Asia (n = 10) (%)	OA (n = 5) (%)	EU (n = 28) (%)	Total (n = 146) (%)
Alpha-stat	15	14	50	20	21	19
pH-stat	35	29	30	40	18	31
Mixed	50	57	20	40	61	50

NA, North America; CSA, Central and South America; OA, Oceana; EU, European Union.

be an effective method of increasing the response rate. In some regions, the response rate was quite good (over 80%), which increased the likelihood that our sample was representative of current practice in these areas. In other areas, the response rate was less than 30% and perhaps more prone to sampling bias (see Table 1). Furthermore, some regions (eastern Europe, Middle East, China, and India) are not represented. However, this survey is a representative sample from a global perspective in that it summarizes the practices used during nearly 30,000 annual procedures from 146 programs.

There were regional differences in the use of some safety devices. Air bubble detectors were used more commonly in NA and OA (96% and 100%) than Asia, CSA, and EU (70%, 50%, and 79%, respectively). Wide variation in the use of one-way valves (in sucker/vent lines) exists across all continents with a range from 7% to 90%. In addition, the use of a gas supply oxygen analyzer was variable from 40% to 100%. Some of this variation is likely related to variation in regional published practice standards. However, in some cases, we noted that clinical practice was not consistent within regional published standards. For example, American Society of Extracorporeal Technology's current Essentials and Guidelines mandates use of a bubble detector and suggest the use of one-way valves and gas supply oxygen analyzers. Although bubble detectors and one-way valves are widely used, gas supply analyzer use was reported at only 40% of NA centers. Organizations that write standards and guidelines might gain insight from this survey on areas where practice is not consistent with their written guidelines.

Although the survey provides insight into particular areas of consensus in practices, these areas of consensus should not be presumed to be "evidence-based" or "best practice." To this point the survey is useful for identifying gaps between the evidence-based and current institutional practice. For example, the use of "closed" reservoir CPB systems is uncommon; however, the preponderance of the published evidence related to open vs. closed reservoir systems demonstrates improved measures of inflammation and fibrinolysis when using a "closed" system (9–11). Open systems are more common as a result of their ease of use and use for providing VAVD. Further research is required to identify the safest, most effective, and efficient perfusion system to minimize inflammation, platelet dysfunction, and hemodilution. Arterial–venous modified ultrafiltration (A-V MUF) was used by 62% of reporting centers. Geographic variation exists with 69% of centers in NA using A-V MUF vs. 43% in EU. The use of MUF has been shown to reduce inflammatory mediators, improve cardiac function, and reduce pulmonary vascular resistance after CPB (12). According to previous surveys, the use of MUF has steadily increased (42% use in 1994, 64% in 1999, and 75% use in 2004 in NA) (6,7). The current survey indicates a similar rate for MUF across other geographic regions at 71%.

Variation also occurs when technical innovations emerge. However, the rate of diffusion of these new innovations is often quite variable. For example, oxygenators with integrated arterial line filters were recently introduced into practice and the survey showed their reported use was 23%. The use of integrated arterial line filters has been shown to reduce prime volume when compared with the traditional standalone arterial line filters (13). With a premium placed on prime reduction, one would expect the use of integrated arterial line filter oxygenators to surpass the traditional standalone devices in the future.

Rodgers (14) describes a theoretical framework for explaining the diffusion of innovation. Five characteristics, relative advantage, compatibility, complexity, trial ability, and observe ability, influence the rate of change. Rodgers further went on to describe five categories of adopters of new ideas: innovators (quickest to adopt), early adopters, the early majority, the late majority, and laggards (last to adopt). Each group adds a uniquely valuable perspective. The latter add historical context, and although this group diminishes the rate of change, they add value by their insistence on strong evidence before making a change. They are less deliberate but more cautious. Such a framework provides an apt lens for our profession and may provide insight to interpreting our present analysis. The rate of diffusion across centers may reflect a learning curve, a lack of sufficient evidence that shows the benefit of the proposed change, or social factors related to those proposing the change. Economic factors may also have a role in the rate of change. Stammers and Mejak (15) documented that cost pressures may have great influence over decisions to use various devices even when they are known to have superior safety and effectiveness.

Recently there has been an interest in myocardial protection for complex congenital heart surgery, in particular use of hyperpolarizing (Custodiol® HTK) and modified depolarizing (Del Nido) solutions. There is a growing body of evidence and experience that these solutions may provide effective myocardial protection using a single-dose technique (16,17). Our survey confirms the adoption of this change with 32% of reporting centers using one of these two solutions. These solutions are designed to increase the safe ischemic time and facilitate fewer interruptions in the operation to administer subsequent maintenance cardioplegia.

We recognize some limitations to our current survey. First, we acknowledge that there may be some lingering misinterpretation for some questions within or across regions of the world. Nonetheless, we identified 10 perfusionists from 10 different countries to pilot the survey. Based on their feedback, we modified, reconstructed, or eliminated questions that were found to be confusing or

irrelevant to some regions of the world before the release of the final version of the survey. Although these efforts certainly improved the survey, we, nonetheless, found lingering issues with misinterpretation of questions by some segments of the surveyed population. One multiple-part question in particular asked for a response of the lowest acceptable hematocrit (%) during different types of CPB. It is suspected that some respondents may have replied using grams per deciliter of hemoglobin as opposed to hematocrit (%). This could explain the startling low-end values of the range (8% noncyanotic and 10% cyanotic) revealing that some aspects of the survey design did not allow for adequate explanation. Although there was no way of knowing for certain what their intentions were, the benefit of such a good response rate (51%) is that a few outliers will not greatly alter the results. In addition, while investigating the reason for low response rates in certain regions of the world, we learned that some of our international colleagues found the survey difficult to complete as a result of questions and multiple-choice selections that were inconsistent with their local practice. This finding is likely related to geographic differences in technological and educational resources and highlights the need for an improved understanding of international practice.

The findings document the wide-scale variability in practice in 2010. Future work will focus on identifying opportunities for reducing unwarranted variability in practices across our profession, irrespective of geography.

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