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Common Perfusion Problems

Schabel RK, Berryessa RG, Justison GA, Tyndal CM, Schumann J. Ten Common Perfusion Problems: Prevention and Treatment Protocols. J Extra Corpor Technol. 1987;19:392–398.

In this issue of *JECT*, Charrière et al. (1) report the results of the fourth retrospective perfusion safety survey since Stoney et al. (2) and Kurusz et al. (3) published their survey results in 1980 and 1986, respectively. As a bonus in this issue, Mark Kurusz comments (4) on Charrière's article and their "carefully collected data."

Searching the keyword "survey" in the *JECT* article database yields seven publications reporting retrospective results in the areas of education, safety, research, pediatrics, extracorporeal membrane oxygenation (ECMO), equipment, and devices. Only one safety-related survey (5) has been published in *JECT* prior to this issue.

In 1987, Romana Schabel, a student at Oakland University's perfusion education program, worked with several of her clinical instructors (who were PSICOR, Inc., clinicians) to author preventive and corrective actions for the most commonly identified perfusion problems at the time (6). Ms. Schabel and her coauthors built on the sentinel survey work of Stoney and Kurusz, and their coworkers. And, isn't it regretful that we have not yet eliminated the majority of these perfusion problems today?

Schabel's article supplements an early gap in the pre-2000 *JECT* body of knowledge regarding safety survey results. The authors of this issue's classic article leveraged PSICOR's corporate policies and procedures to share their approach to preparing for and avoiding high-probability clinical perfusion problems. Schabel's team moved beyond just counting clinical incidents to planning how to decrease the occurrence of the events.

Considering today's environment and desire to reduce medical errors, Schabel and her coworkers were ahead of their time. Considering perfusionists are still experiencing some of these problems in our modern practice . . . there is still more work to be done. Reviewing our classic article is a reminder of how to apply survey information and good patient care department team behaviors (quality meetings, incident-reporting, checklists, etc.) to avoid and be prepared for possible perfusion incidents.

Schabel's Figure 1 is an early perfusion team model for applying today's accepted failure mode and effect analysis, human factors analysis and Six-Sigma process improvement strategies from defining problems to monitoring the success of protocol changes (7,8).

The time for prospective reporting of perfusion incidents is here. Despite Charrière's good and timely work, there is little reason to ever publish another retrospective perfusion incident survey. All perfusion safety surveys should be prospective. Perfusion teams should have protocols in place to electronically capture equipment and patient-related incidents and events—then retrospective surveys would not be needed.

The Society of Thoracic Surgeons just posted their Cardiothoracic Safety Reporting System (http://ctsrs.ctsnet.org/) where The Cardiothoracic Surgery Network (CTSNet) members may contribute an incident vignette so that others may learn with the goal to improve outcomes. The Australian and New Zealand College of Perfusionists supports a prospective perfusion incident reporting system based on the work described by Jenkins, et al. (9) and described by Baker and Wilcox (10). A national contract group (11) and study groups like the Northern New England Cardiovascular Disease Study Group have successfully designed prospective reporting systems (12). The International Consortium for Evidence-Based Perfusion (13) and AmSECT know that U.S. perfusionists should be participating in a prospective incident reporting database.

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Conflict Statement: Mr. Riley served as Director of Quality and Education at PSICOR, Inc. and was editor of JECT when this article was published. PSICOR, Inc. was a co-sponsoring institution for the Oakland University perfusion education program.

The next multi-institutional national perfusion safety survey results we read in *JECT* should come from cardiac surgery teams participating in a prospective incident reporting system and employing Six-Sigma process improvement activities such as those described twenty years ago by Schabel and her coworkers.

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Ten Common Perfusion Problems: Prevention and Treatment Protocols

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Abstract

(*J. Extra-Corpor. Technol.* 19[3] p. 392–398 Fall 1987, 30 ref.) Research has been done regarding the unfortunate consequences of cardiopulmonary bypass (CPB) problems, but written recommendations for preventing these problems have not been addressed. There are few, if any, commonly accepted protocols (which may decrease morbidity and/or mortality) to deal with specific perfusion accidents. We studied reports dealing with the incidence and nature of perfusion complications and found the most common perfusion problems included: protamine reaction, hypoperfusion, oxygenator failure, blood clotting within the extracorporeal circuit, line separation, gross contamination, transfusion errors, drug errors, gas embolism, and electrical failure. The purpose of this paper is to identify the perfusion problems that are "most likely" to occur, to recommend preventive measures, and to give examples of emergency protocols for treatment of these events. It is felt that the risk of perfusion accidents can be decreased through the use and practice of written prevention and treatment protocols and we recommend that perfusionists, surgeons, and anesthesiologists together do a failure analysis of their own systems and develop prevention and treatment protocols designed for their own needs.

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Introduction

It is estimated that between 2,000 and 10,000 lives per year could be saved in this country alone if efforts were successful in preventing needless operating room deaths.[1] In cardiopulmonary bypass (CPB), one of the most technical of surgical procedures, morbidity and mortality is too high. The need to decrease the risk of CPB procedures has been well documented. In two retrospective surveys, it was concluded that perfusion accidents occur in 1 out of 300 CPB procedures, and 1 in 1,000 end in serious injury and/or death.[2,3] Because these are retrospective studies, these estimates may be low.[3] In a recent review of the literature, sixty to seventy percent of patients who undergo CPB will have at least transient neurological dysfunction post-bypass.[30] This is only one of a number of pathophysiologic changes that occur with bypass procedures. It cannot be overstated that these statistics are tragic and unacceptable.

Because CPB is not a straightforward, predictable controlled procedure, ECRI and others have recommended that written protocols be utilized.[4] According to Kurusz, over fifty percent of perfusionists do not use protocols, indicating the importance of educating the surgical team to develop and use written prevention and treatment protocols.[2] The purpose of this paper is to discuss 10 of the most common perfusion problems identified in the literature, and to give an outline for prevention and treatment of these problems. We will also suggest a method of developing procedures and protocols in an effort to assure quality perfusion.

Materials and Methods

We reviewed the literature dealing with the incidence and nature of perfusion complications ranging from equipment to personnel. Three major studies were used as a basis: *Cardiopulmonary Bypass Systems: A Study of Safety and Performance,* a Food and Drug Administration sponsored study published in 1980 by Mortenson et al., a survey published by Stoney et al. in 1980 of 349 cardiac surgeons, and a recent survey of over 608 clinical perfusionists by Kurusz et al.

After the literature review was completed, a management method for quality assurance was needed in order to suggest a philosophy for developing the protocols for the most common perfusion problems found by the above studies. The importance of preventing problems was outlined in Philip B. Crosby's book, *Quality is Free* and was used for this purpose.

Results

Identification of Problems

From our review of Mortenson et al., Stoney et al., and Kurusz et al., the perfusion problems identified in Table 1 appeared to be the most likely to occur. It should be emphasized that perfusion problems are not limited to these shown. These system failures can be divided into equipment and personnel types, found in Column I. Columns II and III give examples of prevention and treatment protocols for these failures.

"Protamine reaction" (Kurusz) and/or disseminated intravascular coagulopathy (DIC) (Stoney) were indicated as the number one cause of morbidity and mortality in bypass procedures by Kurusz and Stoney. Gas embolism, although identified less frequently by perfusionists in Kurusz's later study, was still catastrophic when it occurred. It was the third leading cause of morbidity and mortality.

Recommendations

The lack of a disciplined method of openly attacking problems breeds more problems.[5] An important step in developing protocols is to be able to apply the 4 steps of problem solving theory: identification, evaluation, resolution, and reassessment. Identification of a particular perfusion problem can be approached in several ways:

1. case presentations
2. morbidity and mortality reports
3. incident reports
4. complaints and/or comments from staff
5. occurrence screens (documentation)
6. direct observation
7. literature reviews
8. equipment bulletins
9. society bulletins
10. risk management data (surveys/studies)
11. drills
12. education

Through these activities, one can evaluate whether a particular problem is most likely to fail (or perhaps already failed) in their own system. Identification and evaluation completed, one can develop a written protocol designed to resolve that problem. After the protocol has been written, read by the surgical team, and implemented for a preplanned time period, one should go back to step one in order to reassess the status of the problem; in more simple terms, "Is the protocol working?" See Figure 1 for a simplified approach to problem solving.

The actual design of a written protocol can be more difficult; however, one can create solutions to complicated problems by breaking that complicated problem down to its basic cause.[5] First, write down all the potential causes that could result in particular failure. Second, keeping in mind that protocols are answers to questions, state the goal of the protocol in question form.

The methods for identifying a problem can also be the best aids for ideas of what should be included in the protocol. Ask colleagues what has worked for them in the event of that problem, and conduct research for solutions used with good results.

Protocols should be written in a form that is easy-to-read, implement, and follow. Different forms may include step-by-step procedures, outlines, and/or checklists.

Discussion

Protocols are answers to questions.[5] In perfusion, these protocols will deal with personnel, equipment, and standards of perfusion practice, i.e., "How many perfusionists will be used per bypass procedure?", "What type of oxygenator will be used for patients over 100 kilograms?", or "What steps should be followed in the event of an air embolism?"

Variances are a failure to meet the standards required for a procedure or task.[5] Variances often occur when protocols are not used. Protocols should be designed to prevent variances of all types: uncertainties, unexpected events, failures, and/or human error. The effect of a variance of one type (i.e., equipment failure) may be complicated by a variance of another type (i.e., an inappropriate reaction in the event of an equipment failure). Human error is thought to be responsible for most variances 72% of the time,[2] again emphasizing the importance of developing and using a protocol to prevent a variance.

Table 1

Ten Common Perfusion Problems: Suggestions for Prevention and Treatment Protocols

Variance	"What can we do to prevent this event from occurring? What can we do to be prepared in the event of this variance?"	"What do we do in the event of this variance?"
"protamine reaction"	a. use slow injection[15] b. give peripherally[15] c. give 5–10 mg test dose[15] d. careful history taking; use with extreme caution in:[15] • patients with poor LV function • vasectomized patients • patients with prior protamine exposure • diabetics using NPH insulin • patients allergic to fish e. keep CPB circuit intact during protamine administration f. protamine substitutes (i.e., Hexadimenthrine, not available in U.S.)[13] g. use of low molecular weight heparin[16] h. base protamine dose on ACT, circulating heparin[21]	a. administer fluids for hypotensive reactions[15] b. give oxygen, steroids, epinephrine (5 mcg/kg), antihistamines (diphenhydramine .5-1mg/kg), and positive pressure ventilation for analphalactoid-type reactions[15] c. alpha vasopressors 10–40 mcg), CaCl (7–15 mg/kg) and dopamine for myocardial depression for idiosyncratic reactions[15] d. administer heparin[17] e. reinstitute CPB to stabilize, if necessary
air embolism	a. careful priming techniques b. flush system with CO_2 c. level sensor (check alarm) d. bubble detector (check alarm) e. arterial filter/bubble trap f. look for emboli postCPB in arterial cannula before retransfusing g. check monitoring lines for air before flushing h. check roller head direction i. cardiotomy reservoir vent open j. 100% occlusion of LV vent pump head k. use of vacuum system on membrane oxygenators[28] l. limit traffic around pump m. check all connections, secure with tie-wraps n. one-way purge lines off any arterial site o. one-way LV vent pressure relief valve, check under fluid	a. use of "battle plan" for automatic arterial pump head shutdown[27] b. use of "battle plan" for massive air embolism during CPB[27] c. retrograde perfusion[3]
oxygenator failure	a. check all gas connections to: • oxygenator • correct gas sources • kink-free gas lines • liquid-free gas lines b. use largest oxygenator possible for patient without compromising priming volume c. use flow meters with an FiO_2 blender (membrane oxygenators)	a. open recirculation line, if possible, and increase flow b. change out oxygenator • use 2 man perfusion • preprimed oxygenator technique[9]

Table 1 (continued)

Ten Common Perfusion Problems: Suggestions for Prevention and Treatment Protocols

Variance	"What can we do to prevent this event from occurring? What can we do to be prepared in the event of this variance?"	"What do we do in the event of this variance?"
	d. calibrate flow meters and blenders regularly e. do not allow O_2 debt to become so great that "catching up" is not possible f. perform oxygenator change-out drills[9] g. be able to adequately diagnose oxygenator failure[9]	
electrical failure	a. be familiar with your institution. Will emergency generator automatically come on or will you need to plug into auxillary power? b. inspect cords and plugs before every pump run c. utilize plugs that "lock-in" d. check flashlight before every pump run, put in accessible place e. have hand cranks immediately accessible f. have battery operated emergency lights in OR	a. grab/clamp venous line to avoid exsanguination b. have assistant shine light on reservoir c. shut off pump d. hand crank to previous blood level and/or resistance e. have backup hand crank suction/vent/CP pump f. have surgeon bathe heart with saline slush to avoid heart rewarming if hypothermic
hypoperfusion	a. add crystalloid/colloid as needed; blood if HCT is low b. watch line pressure at initiation to insure proper cannulation c. scan venous line for air d. set occlusion before every case e. when using centrifugal pump, always scan flows as higher resistances can decrease flow f. monitor venous O_2 saturations closely	a. increase flow—add fluids b. have backup perfusionist "walk" venous line air locks back to reservoir from table
drug errors	a. label all syringes b. have backup watch as drugs are drawn c. tape bottle to syringe d. use color-coding of syringes e. have backup give drug to primary as requested; both should verbally acknowledge what drug is and what dose is given f. document all drugs and dosages administered g. communicate with anesthesia and/or surgeon regarding use of non-protocol drugs	a. consult anesthesia and/or surgeon
blood clotting within extracorporeal circuit	a. add heparin to prime b. monitor activated clotting times (ACT) closely: • prior to bypass have adequate (>480 seconds) ACTs[23] • during bypass >480 seconds[23]	a. add heparin as needed to increase ACT, utilizing dose-response curve[21] b. in evident blood clotting, discontinue CPB as soon as possible c. change out circuit

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Table 1 (continued)

Ten Common Perfusion Problems: Suggestions for Prevention and Treatment Protocols

Variance	"What can we do to prevent this event from occurring? What can we do to be prepared in the event of this variance?"	"What do we do in the event of this variance?"
	c. keep circulating heparin at >300 units/kg during CPB[19] d. use of heparin-coated filters within circuit e. shut off pump suction before protamine administration f. use autotransfusion unit when heparin is not circulating for blood salvage g. careful history taking; does patient have history of hypercoagulation? h. use of prostacyclins (Iloprost) to avoid platelet aggregation[29]	
gross contamination	a. gown and glove during circuit preparation if necessary to make cuts and connections b. do not allow set-up "wet" pump to sit for extended periods of time c. limit traffic around pump d. educate staff to sterile technique e. do not remove sterile lines from table until it is deemed that emergency resumption of CPB is unlikely to occur f. use of sterile blades and/or scissors when making cuts on primed pump in conjunction with alcohol and/or betadine swab at site of cut g. be certain of sterile package integrity	a. use of applicable antibiotics to patient (IV and/or topical) as deemed by anesthesia and/or surgeon
line separation	a. check all circuit connections b. secure all connections with tie-wraps c. special attention should be paid to silastic tubing connections; tie-wrap these prior to priming d. count clamps; check positive side of pump for clamp position before roller head advances e. monitor line pressure closely as roller pump head begins to advance f. shut off pump head if like pressure "peaks" g. use of line resistance alarm/shut off systems h. perform emergency drills i. visually check arterial line	a. shut off pump clamp venous and arterial lines b. make necessary connections, fill lines with fluid c. aspirate air from arterial line, if applicable resume CPB as soon as possible
transfusion errors	a. document patient's identification number and blood type on pump record prior to bypass[18] b. have anesthesia and circulating nurse check blood before it is checked by pump personnel and/or anesthesiologist[18]	a. stop transfusion immediately[18] b. notifiy appropriate personnel[18] c. recheck all labels, charts, and forms to determine if correct type/RH was given[18] d. obtain urine specimen[18]

Table 1 (continued)

Ten Common Perfusion Problems: Suggestions for Prevention and Treatment Protocols

Variance	"What can we do to prevent this event from occurring? What can we do to be prepared in the event of this variance?"	"What do we do in the event of this variance?"
	c. only physician will deem if blood components are necessary[18]	
	d. patient identification:[18] • identify patient • patient's hospital number • verify blood type and RH factor • verify crossmatch number This should verbally be communicated between both pump personnel, or perfusionist and another member of surgical team	
	e. check expiration date on blood bag before administration[18]	
	f. always double check before administering blood to CPB circuit[18]	
	g. do not store blood in unmonitored refrigerators[18]	
	h. return blood to cooler/monitored refrigerator if not immediately used	
	i. be aware of signs of transfusion reactions[18] • hematuria • analphylaxis	
	j. remove all blood products after patient leaves OR	

The goal of prevention and treatment protocols should be the assurance of quality perfusion for *every* patient. "Quality does not assume luxury, goodness, shininess, or weight."[5] It is defined as "conformance to the standards required," or in other words, the protocol. Realizing what quality is, as well as how to measure it and what leads to it, makes quality possible. Emergency (treatment) protocols should be short, to the point, and limited to one page only. Copies of emergency protocols should be kept in an easy-to-reach place for quick reference in the event of an emergency.

Implementation of a protocol cannot take place unless everyone has read and understood the protocol thoroughly. To ensure that everyone has read and understands the existing protocol, drills should be performed on a regular basis. Drills provide at least a

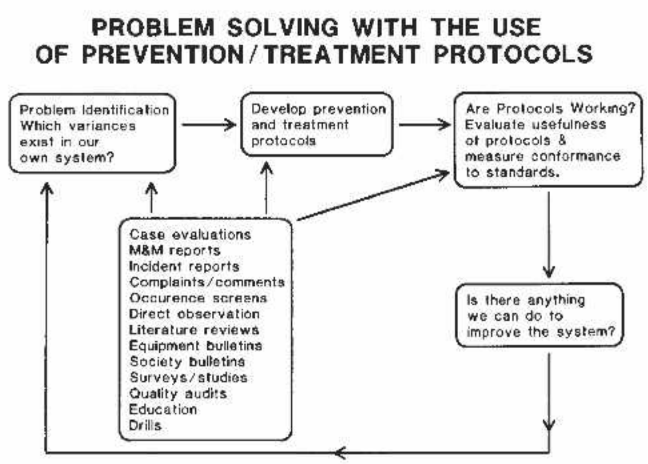

Figure 1: Problem Solving and the Use of Prevention/Treatment Protocols

fourfold benefit: educating the surgical team to new techniques and procedures, shortening reaction time in emergencies, evaluating the existing protocol, and enhancing communication between different members of the surgical team.

Checklists should be utilized prior to bypass. Written checklists help make personnel accountable. It should be realized that having a checklist alone will not prevent problems. Although 77.5% of perfusionists use checklists, 61.3% of these use "mental checklists."[2] A written checklist, followed carefully and thoughtfully, should.be used by the perfusionist and assistant. It is also recommended that the assistant use the checklist first, as it is possible that the primary perfusionist may have preconceived notions about what has been completed on the pump set-up and prebypass procedures.

Not only do quality failures cost money; quality failures cost lives. Designing and implementing protocols should not be considered merely a legal issue but also an ethical one. Quality perfusion is more than avoiding liability or risk management, and more than not harming the patient. It is doing the right thing right the first time. Personnel who care will do this.

According to Bob Waterman, author of *In Search of Excellence*, "when two people are working with equal technical skills, the one who cares will do the better job . . . quality comes from caring." It is the authors' contention that written protocols, used thoughtfully and reassessed on a regular basis, are the first and one of the most important steps in making quality perfusion possible.

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