Safe Perfusion- why are Checklists and Simulation Effective?

At the conclusion of this lecture, the participant should be able to:

1. Recognize the need for enhanced communication in and out of the operating room.
2. Recognize the value of simulation in learning to deal with uncommon but life-threatening situations and to identify human error.
3. Utilize checklists in the operating room.
4. Discuss the impact that simulation and checklists have had in the peri-operative environment.

Introduction: How safe is perfusion? Numerous surveys have been conducted in various countries over the past four decades which suggest that errors continue to occur at a rate of about 1 of every 200 cardiopulmonary bypass (CPB) procedures. Equipment malfunctions and operator error cause death or permanent injury occurs at a rate of 1/2500 procedures, a rate approximately 100 times greater than that of general anesthesia. When a catastrophic incident occurs during cardiopulmonary bypass it requires the delivery of a complex, coordinated response by a team under time pressure, which, unfortunately, cannot be practiced in the real world.

<table>
<thead>
<tr>
<th>Country</th>
<th>pump related incidents</th>
<th>Permanent Injury Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoney 1980</td>
<td>1/300</td>
<td>1/1,000</td>
</tr>
<tr>
<td>Wheeldon 1981</td>
<td>1/400</td>
<td>1/1,500</td>
</tr>
<tr>
<td>Wheeldon 1981</td>
<td>1/140</td>
<td>1/1,800</td>
</tr>
<tr>
<td>Kursz 1986</td>
<td>1/100</td>
<td>1/1,000</td>
</tr>
<tr>
<td>Jenkins 1997</td>
<td>1/135</td>
<td>1/1,300</td>
</tr>
<tr>
<td>Mejak 2000</td>
<td>1/138</td>
<td>1/1,453</td>
</tr>
<tr>
<td>Charriere 2006</td>
<td>1/198</td>
<td>1/3,222</td>
</tr>
</tbody>
</table>
The contribution of human factors to errors in cardiac surgery is becoming increasingly obvious. The greatest opportunity for future improvement in cardiac surgery is not related to technology but rather in the area of improving both individual performance and team interaction. Or one might say areas for improvement are at the locus of the individuals interface with equipment and also at human to human interaction interface.

The aim of this presentation is to discuss the role of checklist and simulation in improving human performance and interaction to reducing problems (errors) related to cardiac surgery and cardiopulmonary bypass.

Generally speaking three types of problems confront cardiac surgical teams; the simple, the complex and the complicated, shown on the Stacey Matrix below.
Simple problems may be addressed with the use of checklists. Checklists are extremely effective for making sure that simple procedures are carried out safely and with accuracy. Implementing checklists in surgery has been shown to reduce errors in surgery and the morbidity and mortality associated with these errors. Checklists should be applied to areas where there is strong agreement and certainty (referred to as the simple domain in the Stacey Matrix). By using checklists for simple domain issues, the clinicians mind is less occupied with the simple issues, allowing for more focused thought in the complicated and complex domains.

**Checklist may be used in a number of ways:**

1. They are used to evaluate a patients “readiness” for surgery and should include lists of necessary tests, acceptable laboratory values to proceed ahead with surgery for a particular patient. Readiness checklists should include hard-stops that will trigger postponing a procedure if readiness criteria are not met.

2. A checklist may be used to verify that all of the evidence-based elements of a process have been completed for a particular process. Central line bundle checklists are commonly used for line placements in surgery and throughout the hospital. Such checklist have been shown to be effective in proving safety in that patients are less prone to interactions when such bundles are adopted.

3. Since the early 1970’s perfusionists have employed checklists to verify proper calibration and set up of CPB devices. Checklist have served to improve the likelihood of users interfacing correctly with the device during the set up procedure and assure that certain steps in the procedure have been performed prior to the initiation of CPB.

4. Checklists are also used as an aid when non-routine procedures are performed to help perfusionists to remember all of the steps in a process. For example a checklist may be employed when circulatory arrest or selective
cerebral perfusion is used to verify that all of the appropriate medications have been administered, that adequate cooling been completed, laboratory tests have been performed, and the CPB circuit has been properly configured.

5. A checklist may be used to make sure all of the drips and medications for a cardiac procedure are properly compounded and prepared for delivery.

6. Checklist may also be used as a hand off tool when transferring coverage of a patient.

The American Society of ExtraCorporeal Technology’s published standards of practice states the following standard and guidelines related to the use of checklists:

**Standard III: Checklist**

*Perfusionists must use a checklist for each cardiopulmonary bypass procedure*.¹

*Checklists must be included as part of the patient's permanent medical record*

*Guideline 3.1*: A perfusionist should consider using checklists in a read-verify manner.

*Guideline 3.2*: A perfusionist should utilize a checklist throughout the entire peri-operative period (eg set-up, pre-bypass, initial onset of bypass, prior to cessation of bypass, post bypass, and any required return to bypass)

*Guideline 3.3*: Checklists should be employed for other ancillary perfusion services that may be utilized in conjunction with cardiopulmonary bypass (e.g. cell salvage, intra-aortic balloon pump, extracorporeal membrane oxygenation.) These services may be provided by associates of one’s institution, and performed in conjunction with a perfusionist.

**The Role of Simulation**

For problems in the complex and chaos domains of the Stacey Matrix, simulation may be effective since successful action in these situations requires a coordinated effort of team members with a shared mental model. Unfortunately, at times cardiac surgery teams have a tendency of think about their work and
tasks in a mechanistic way. This type of thinking as been described as follows by Peter Senge at the Center for Organizational Learning at MIT:

“From an early age we are taught to break apart problems, to fragment our world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of connection to the larger whole.”

An example of such simplified mental models or a mechanistic view is as follows:

- **Surgeon**- I make decisions and I perform the technical part of the operation. I rely on others to do their part.
- **Anesthesiologist**- I put in the lines and keep the patient safe and relaxed during surgery. I keep the patient’s interests in mind.
- **Perfusionist**- I am responsible to provide adequate perfusion to the patient. I must maintain the flow, pressure, and acid base balance. I will not trouble the surgeon with little problems. If there are big problems I will inform him, chart it and it will be his responsibility.

This type of thinking is not effective when the team is faced with complex tasks or challenging problems. When team members do not have an understanding of the implications of their actions on others and adhere to a narrow mental model, their actions may be ineffective, poorly coordinated or, in some cases, may have an adverse effect on the patient or on the ability of other team members to successfully execute their work.

Cardiac surgery teams should be viewed as complex adaptive systems (CAS). A CAS is a group of individual agents, who have the freedom to act in ways that are not always totally predictable, and whose actions are interconnected such that one agent’s actions change the context for other agents. Agents are the
individuals that comprise the team. Agents act according to their own set of internal rules or mental models sometimes referred to as schemata. Agents are capable of changing their mental models and also have the ability share mental models with other agents. Small changes in the mental models cause the system to adapt and change sometimes in big ways.

Simulation is helpful for teams and individual team members in that it provides a safe venue to practice complex tasks and gain context knowledge about complex problems. Following a simulated task the team debriefs and reflects on what has transpired. Such debrief provides the opportunity for the team members to think more broadly and to understand the interconnectedness of team member actions, to discover tacit knowledge and to develop a mental model that is shared.

Simulation is also useful in that it creates a space for the structured assessment of “new” technologies, potentially allowing for creation of better environment for the roll out of new technology providing end users with a true understanding of and ability to actually safely use new technologies. It allows for this assessment to take place in a team training oriented environment that is safe. Simulation laboratories provide a venue where technology can be carefully assessed prior to significant capital expenditure. It also provides an opportunity for repetition, assessment and refinement of emergency procedures.

Over the past decade cardiopulmonary bypass simulation has emerged as an important tool for teaching individuals skills and for assessing the technical and non-technical skills of individuals and teams. High fidelity simulation is especially effective for teaching crisis management during cardiopulmonary bypass since it allows the team to be exposed to cognitive challenge, stress, and physical demands without exposing the patient to risk.
In aviation, simulation training is widespread and is used to train individual skills, assess the technical and non-technical (NT) skills of individuals and teams, and study how errors occur and how they can be prevented. Medicine has been slow to adopt simulation training, but the technical and educational tools and techniques that underpin High Fidelity Simulation Training in medicine are undergoing rapid evolution and development. Simulators are emerging as a valuable tool for teaching procedural skills and measurement of skills. Such assessment is becoming part of the licensure process in some areas of medicine.

Simulators show promise for assessing and training cardiac surgery personnel in NT skills. Current patient simulators provide highly realistic physiologic data with real clinical equipment, presenting accurate and believable clinical scenarios. This technology requires educators to design curricula and evaluation rubrics and to document the validity of the educational environment. Although much of the initial research focused on technical skill training and assessment, recent evidence supports simulation for team training and the development of NT skills.

In the simulated OR, team communication and tactical responses to challenging clinical problems can be practiced, and accurately evaluated and measurably improved. Repetitive practice can prepare the clinician for an unexpected event by attenuating emotional arousal to a level that allows optimal performance.

Simulation is particularly suited for training in CPB emergencies and was first described in 1977. Computer controlled hydraulic models of the adult and paediatric human circulation exists for training in CPB, and can be configured to simulate routine or crisis scenario. Virtually 100% of perfusionists surveyed in 2002 believed that such practice would be beneficial, but only 17% reported that such drills occur.

**Summary:** Checklist and Simulation are effective tools for improving human interaction and team performance which results in improving the safety of CPB.
Appendices

Accident Surveys


2 Peter Pronovost, M.D., Ph.D., Dale Needham, M.D., Ph.D., Sean Berenholtz, M.D., David Sinopoli, M.P.H., M.B.A., Haitao Chu, M.D., Ph.D., Sara Cosgrove, M.D., Bryan Sexton, Ph.D., Robert Hyzy, M.D., Robert Welsh, M.D., Gary Roth, M.D., Joseph Bander, M.D., John Kepros,