Online Table A: Classification of Hazards Identified in Cardiac Surgery Work Systems

SEIPS Categories	Subcategories	Hazards	Specific Examples from Cases
Care Provider	Knowledge and skills: The fit between an individual's qualification, training, education, and/or skills with respect to a particular task.	(1) Inadequate/ insufficient knowledge or skills for a task due to lack of education, experience or training.	A surgeon asked a technician for a piece of equipment with which the technician was unfamiliar. This unfamiliarity delayed the progression of the surgery. Anurse stated that this piece of equipment was newly purchased and did not look like the old one, and that neither the nurses nor the technicianshad beeninserviced on it.
	Professionalism: Any behavior by a cardiovascular operating room team member that can affect the safety of care directly or indirectly (by affecting the professional relationship between care providers or between care providers and patients).	(2) Inadequate/ lack of professionalism such as not respecting other providers. May include a hierarchical culture where offenders do not expect to be disciplined.	A surgical team waited for the attending surgeon to come to the operating room and initiate the time-out. The circulating nurse had called to notify him 18 minutes earlier. The anesthesia attending physician (who was covering multiple rooms) checked repeatedly to see if the surgeon arrived and finally said he was going to call him. The surgeon had been in his office doing paperwork. This behavior caused unnecessary exposure of patient to anesthesia. 2: An anesthesiologist took multiple personal calls during a case and was observed to administer a dose of midazolam to the patient without putting the phone down.
	Individual practice variations: Differences among individual care providers within the same institution in performing tasks and procedures in ways that are not supported by evidence, specific patient needs or research; rather driven by authority, habits, experience or preferences of individual care providers.	(3) Non-standardized approach to care delivery and/or task performance due to habits, preferences, education, and previous experiences of individual care providers that may not be based on the current evidence.	1: Despite the availability of national evidence-based recommendations, each surgeon within an institution has an individual algorithm for heparin reversal, leading to variations in protamine dosing. This results in confusion among staff.
Task	Job demands/ workload:The burden or cost incurred by an individual in performing direct and indirect	(4) Unexpected fluctuations in demands (eg non-emergency case added to the OR schedule) (5) Unnecessarily increased	A new casewas added to the schedule in the morning. This unexpected change in plans had a negative impact on the cardiac surgery team's ability to review

	activities of care that reflect the combined effects of demands imposed by the cardiovascular operating room environment.	workload due to sub-optimal design of other elements of the work system (6) Production pressures	patient's full history. It also negatively affected nursing preparation time as indicated by several nurses.Multiple care providers noted that in this organization there is significant amount of pressure from surgeons to work fast, to finish cases quickly, and to get the next case started.
	Non-value adding tasks:Any instance where the cost of performing a task outweighs the benefit,for example, if a taskis performed in an inefficient manner or resources are misallocated.	(7) Poor tool/technology design issues (8) Hardware/software problems (9) Suboptimal purchasing decisions and resource availability (10) Differences or non-alignments in practice between OR and ICU/post-anesthesia care unit	1: Anesthesiologists prepare most of their drug doses rather than having them come prepared from the pharmacy. 2: Perfusionists use paper-based forms during the surgery for documentation and enter the information into the computer in the perfusion room after the case is over.
	Ineffective planning and preparation: Not being ready in a timely manner for performing the tasks and procedures required.	(11) Avoidable time pressure and unexpected changes (12) Ambiguities due to different preferences of surgeons and other care providers (13) Inadequate coordination across units, departments and care providers	The surgeon asked for aortic cannula and then told the perfusionist to heparinize it. The perfusion lines were not ready and should have been prepared in advance in case they need to go on bypass urgently.
	Interruptions:Disruptions not directly related to patient care or to the task at hand.	(14) Someone paging, calling, or entering the ORin reference to another patient (15) Care providers talking about unrelated subjects during surgery	A junior cardiologist came into the OR to discuss another patient with the surgeon. There was a lot of back and forth conversation between the two physicians while the surgeon was starting the operation.
Tools and Technologies	Design and implementation: Any issues due to design characteristics of tools and technologies and/or their deployment in the work system	(16) Poor usability (eg, tangled or kinked lines, non-intuitive interface design, inconsistency in design, poor visibility of system status, difficulties in correcting user errors, user has to rely on memory rather than options and instructions being visible) (17) Inadequate safety features (eg, no redundant checks, no alarms when necessary) (18)Poor fit or misalignment of	1: The IV pump repeatedly alarmed. It was not clear what the cause was to the provider at first. Eventually corrected it. 2: In this hospital they have only one type of perfusion machine that is extremely old and lacks most of the software and other features that are critical for safety. Furthermore, since the perfusion machine is too big, it causes too much hemodilution.

		safety features with users' needs or work as intended (eg too many alarms without prioritization) (19) Size mismatch (too large, bulky) (20) Use of tools, technologies, or supplies with different design characteristics and brands across different sectors of the work environment (operating rooms and ICUs) (21) Lack of integration or interoperability in tools and technologies, causing inadequate support of critical tasks across the hospital	
	Hardware/ software: Any equipment and programming issues except those related to softwareusability	(22) Unreliability of hardware and software performance in a given task (23) Misuse or inadequate use of hardware and software features because they are missing, not installed, hard to use or training about them not adequately provided	1: Oxygen sensors on a perfusion machine may fall from the machine, causing it to shut down without warning at any time. In one case, this required theperfusionist to restart the perfusion machine.
	Availability: The degree to which tools, technologies, supplies and information are readily available when needed	(24) Insufficient quantity of tools and supplies (either in the area where needed or in the hospital) (25) Delay in tool and technology availability at the point and time of need due to, for example, surgical equipment not being sterilized in a timely manner (26) Necessary information not being available due to issuesrelated to tools and technologies	1: Equipment needs to be borrowed from another location. In one case a Doppler was obtained from another operating room during a case, with the nurse telling the surgeon that they did not know how long they would be able to have it: "There is only one Doppler today, we don't know why."
Physical environment	Layout: Workplace allocation and design characteristics of the large scale environment in the operating room suite	(27) Poor planning and design of work area in relation to other parts of the operating room suite and the hospital (proximity of operating rooms to each other, to the storage areas and laboratories, and to the ICU) (28) Insufficiency of size and poor layout design of the operating rooms	1: A technician was called into the room for assistance with placement of airway. The OR is quite small and the anesthesia team did not have very much room to work when placing the airway.

		(29) Poor or inadequate renovation of operating room suite	
	Workspace design: Design characteristics of the immediate work area of individual care providers.	(30)Non-standardization of workspace designs across different operating rooms (31)Inappropriate positioning of equipment and supplies beyond reach of providers (32) Poor configuration of workspacesleading to clutter, inadequate storage and poor organization of tools, equipment, furniture, and cables.	1:In several of the cases observed, medicines in the anesthesia medicine drawer did not seem be in any order, presenting a potential for wasting time in searching for something or selecting the wrong drug. 2: Medications kept in a Pyxis machine that are not directly accessible to the anesthesiologists' work arearequires them to lose sight of the infusion pumps and monitors while getting drugs. 3: Corridors used as receptacles for equipment that should be stored elsewhere
	Ambient environment: Characteristics of the cardiovascular operating room related to human sensory perceptions including noise, lighting levels and temperature.	(33)Noise or loud background music may impair hearing and communication (34)Extremes in room temperature may distract workers (35) Poor lighting may reduce visibility and vigilance	1: In one case, the operating room temperature was never turned back up despite multiple people recognizing that it took a long time to warm the patient.
Organization	Safety culture: The collective (as opposed to individual) approach taken to safety and risk by the organization.	(36) Focus on productivity in expense of patient safety (37) Hierarchical/ top-down culture (38) Limited efforts to identify and mitigate patient safety risks	One anesthesiologist noted: "*This hospital encourages an adversial relationship among staff, often using RN/managers to spy on physicians for the benefit of hospital administration. This destroys any possibility of a team effort for patient care and safety. The administration's motto is "divide and conquer."*
	Education and training: Local policies and practice of preparing front-line and support staff to perform their duties well.	(39) Inadequacy or lack of appropriate structured education and training programs	Surgeon was handed a new brand of cautery gun and was confused: "*Wait a second; does this thing have a special attachment? It's not doing any energy. What am I looking at?*" Nurse stated that it was the first time this brand had been used. The equipment did not work. Further inquiry revealed that the hospital had purchased a new

			type of cautery but failed toinform or train care providers in its use.
	Policies and protocols: Availability, dissemination and shared awareness of structured rules and contingency plans for cardiovascular operating room providers and staff. Includes adequacy of reinforcement and maintenance of quality of rules and plans.	(40) Lack of or poorly organized policies and protocols for care and other processes (41) Inadequate discussion, training and dissemination of protocol and policy changes (42) Poorly developed or reviewed policies and protocols (43) Lack of or insufficient reinforcement of policies and protocols	1: In one hospital, insulin administration was not protocolized, requiring individual doses to be prepared for every patient by a provider with an opportunity for error. 2: In one case, there was a discrepancy regarding when to place ETT fastener devices: whether this should occur in the OR at the beginning of the case or in the ICU just after the surgery is completed. The policy had been changed and not everyone had been informed, leaving the vulnerability for the device to be left off completely.
	Service provision by ancillary services (blood bank, pharmacy, etc.): The quality and timeliness of tasks performed by departments and agencies outside of the cardiovascular operating room and ICU.	(44) Suboptimal performance (45) Delays in services (46) Absence of an ancillary service in the OR suite (eg, no pharmacy in the OR suite) (47) Inadequate ancillary service staff.	1: Surgeon complained that the blood bank lost blood samples for type and matching, requiring intraoperative re-sampling and testing, thus slowing down the case.
	Purchasing decisions: Hospital management's purchasing policies, protocols and behaviors that may impact the delivery of services	(48) Exclusion of front-line providers' input to purchasing decisions that can potentially affect safety of care (49) Poor allocation and management of resources	In one hospital, the brand of infusion pumps used in the OR (Pump A) are different than the brand of infusion pumps used in the rest of the hospital (Pump B). This requires a complete changeover from the intra-operative pump when the patient is transferred to ICU from OR, (i.e., transferring all IV medications and tubing to a new IV pump), a practice which is extremely high risk for giving an inadvertent bolus of a medication or interrupting a vital agent. The decision of buying two different brands of infusion pumps was based totally on costs [Pump B is cheaper but less user-friendly than Pump A]without consultation with providers on the impact of the purchase on care delivery.
	Team factors: Any aspect of the cardiovascular	(50) Team members may not be assertive, may not ask questions	1: Anesthesia: "Did you drain the left chest (asked after the

	operating room group work that have the potential to affect patient safety.	when necessary, may not share pertinent information or know when to ask for help, may not be situationally aware or know how to stay focused on tasks by using distraction management strategies effectively (51) Team members may not have an adequately shared mental model (defined as the degree to which team members share a common understanding of roles and functions of each team member, task requirements and the coordination activities required for providing safe care) (52) Team members not helping to each other adequately (even though they could) (53) Lack of support for teamwork (eg, physical layout having a negative effect on situational awareness of team members) (54) Inadequate mechanisms to hold individual team members accountable	chest was closed)?" Surgeon: "No, is there something wrong?" Anesthesia had seen pleural effusion on the Echo, which could have been addressed but they did not share the information with the surgeon earlier. 2: There was a delay because they did not have the right size aortic cannula and realized this after the incision was already in aorta. This should have been discussed during the briefing.

Online Table B: Classification of Hazards Identified in Cardiac Surgery Processes

Process subcategories	Definitions	Hazards	Specific Examples/ Cases
Care processes	Processes that are used to provide and manage clinical care to patients.	(55) Non-compliance with the recommended guidelines and practices (56) Lack of standardization in care processes	1: Tinted chlorhexidine was used as the skin prep but applied incorrectly. Rather than applying it with friction in a back and forth motion, nurses just painted it on patient's skin. 2: Insulin administration was not protocolized in this hospital, hence the attending anesthesiologist made up a dose.
Other processes	Processes that do not directly related to patient care but support the delivery of the care processes (eg, housekeeping)	(57) Ineffective supply chain management processes resulting in unavailability of supplies and equipment in a timely manner (58) Inadequate or low quality maintenance, repair, and technical support processes (59) Delays in completion of housekeeping services	"I experience at least several instances every week that the supplies or equipment are not available in a timely manner. I think one reason for this is that supply departments have a lack of understanding of clinical needs- urgency and importance are not understood. I cannot do my job if I don't have my supplies and patient will die."