ORIGINAL ARTICLE

Utility of Preprocedure Checklists in the Congenital Cardiac Catheterization Laboratory

Brent M. Gordon, MD,* Teresa S. Lam, MD,† Khaled Bahjri, MD, MPH,‡ Aijaz Hashmi, MD,* and Micheal A. Kuhn, MD*

*Division of Pediatric Cardiology, Loma Linda University Medical Center, †Department of Pediatrics, Loma Linda University Children's Hospital, ‡Department of Epidemiology and Biostatistics, Loma Linda University, Loma Linda, Calif, USA

ABSTRACT

Objective. Preprocedure meetings have become more commonplace in medicine but are not performed routinely in the cardiac catheterization laboratory. We sought to create, implement, and evaluate a preprocedural meeting in the form of a checklist for the cardiac catheterization laboratory. Staff attitudes and perceptions toward safety and sense of teamwork were also analyzed.

Design. All procedures performed in the cardiac catheterization laboratory on patients with structural heart disease from January 2010 to February 2012 were retrospectively reviewed for demographics, procedural details, and reported complications. A checklist was introduced to the preprocedure protocol at the halfway point, and patients were divided into pre- and postchecklist cohorts. Anesthesia and cardiac catheterization laboratory staff were surveyed at the beginning and end of the study period regarding attitude toward safety, team climate, and the impact of errors.

Results. Total number of procedures (prechecklist, n = 371; postchecklist, n = 370) and demographics were similar among groups. Complication rates were equivalent pre- and postchecklist, but there was a greater proportion of interventional cases and higher median complication level in the postchecklist group. Cardiac catheterization laboratory staff reported improved awareness of being briefed with the checklist. Anesthesia differed from cardiac catheterization staff in perception of communication as well as team and safety climate.

Conclusions. A preprocedure checklist for congenital cardiac catheterization cases is easy to perform and serves to update cardiac catheterization laboratory staff. Anesthesia and cardiac catheterization staff had different perceptions of safety and teamwork climate. Further studies are needed to determine if this briefing could lead to better communication among services and ultimately reduce complications.

Key Words. Checklist; Complications; Transcatheter Intervention; Anesthesia

Introduction

Preprocedure checklists have been routinely utilized in the aviation and construction industries to improve safety and limit unexpected events.[1] Recently, checklists have been adopted for use in the surgical arena as a mechanism to potentially reduce medical errors, improve patient safety, limit cost, and prevent surgical malpractice claims.[1–6] Checklists are also thought to improve postoperative care and facilitate transfers between hospital units.[7,8] Pediatric cardiac catheterization procedures can be extremely complicated and associated with significant adverse events.[9–12] In many centers, the cardiac catheterization laboratory (CCL) staff (interventional cardiologists, nurses, and radiology technologists) work closely with anesthesiologists, making the ability to foster teamwork and improve communication between the collective health care team tantamount to patient safety and procedural success. This is especially true as more congenital cardiac catheterization laboratories move toward a system of sedation and anesthesia provided by a dedicated anesthesia staff.

We hypothesized that a checklist designed for the CCL could improve team and safety climates as well as potentially limit complications. With this in mind, we created, implemented, and evaluated a preprocedural meeting in the form of a checklist for the CCL. Anesthesia and CCL staff attitudes and perceptions toward safety and sense of team were analyzed before and after introduction of the checklist.

Methods

After obtaining Institutional Review Board approval, cardiac catheterization records were retrospectively reviewed to identify all patients with structural heart disease who underwent cardiac catheterization from January 2010 through February 2012. Bedside balloon atrial septostomies (n = 17) and hybrid procedures performed in the operating room (n = 4) were excluded for the purposes of this study. There were no other exclusion criteria. Patient demographics, peri-procedure details, and reported complications were recorded. In January 2011, responsibility for administration of conscious sedation was shifted from the operating interventional cardiologist to the anesthesia department.

Patients were divided by age at time of catheterization into neonates (<1 month), infants (1 month to 1 year), children (1–18 years), and adults (>18 years). Interventional procedures were categorized as follows: atrial septal defect/patent foramen ovale device closure, patent ductus arteriosus embolization (coil or device), coarctation of the aorta (balloon or stent), pulmonary balloon valvuloplasty, aortic balloon valvuloplasty, angioplasty (systemic/pulmonary venous and pulmonary artery), stenting (systemic/pulmonary venous and pulmonary artery), and coil embolization (aortopulmonary collaterals and fistulae). Complication severity (levels 1–5) was assigned according to the scoring system defined by the Congenital Catheterization Consortium.[10]

The prechecklist group had a traditional "time out" performed at the beginning of the case that consisted of patient identification and identification of the procedure performed. Any other information provided during this time was at the discretion of the primary operator. A checklist (Appendix 1) that incorporated elements of the traditional "time out" was introduced to the preprocedure protocol at the halfway point of the study period (February 2011), and groups were divided into pre- and postchecklist cohorts. The primary operator or another member of the CCL staff led the team through the checklist before the start of each case. The checklist was usually completed in less than 2 minutes for each case.

Anesthesiologists, radiology technologists, nurses, and interventional cardiologists were administered surveys at the beginning and end of the study period. This survey utilized a 5-point Likert scale (1 = disagree strongly, 2 = disagree, 3 = neutral, 4 = agree, and 5 = agree strongly) to evaluate communication and attitudes toward team and safety in anesthesia (residents, fellows, faculty, and certified registered nurse anesthetists) and CCL (radiology technologist, nurses, and interventional cardiologists) staff. A previously validated study examining safety attitudes (operating room version) was used in the creation of the survey.[13] For the purposes of our survey, the word "surgeon" was replaced with "cardiologist" and "OR" was replaced with "pediatric cardiac catheterization laboratory." Survey responses were compared between groups, as well as among individual groups before and after introduction of the checklist.

Data were analyzed with SPSS version 20 (IBM Corporation, Armonk, NY, USA). Results are given as mean ± standard deviation unless otherwise stated. Chi-squared test and Mann–Whitney *U* test were used to compare results among groups. Fisher's exact test was utilized when n was <5. Survey results were compared using analysis of variance. Significance was set at $P \leq 0.05$. The study was powered to detect a 5% difference in proportions between cohorts.

Results

Patient Population

There were 741 total cardiac catheterizations performed during the study period, with similar numbers in the pre- (n = 371) and postchecklist (n = 370) groups. Patient age, gender, inpatient vs. outpatient status, and total procedural and fluoroscopic time were equivalent among groups (Table 1). General anesthesia was utilized less often in the prechecklist group (72.5% vs. 95.4%, $P < 0.001$). The proportion of diagnostic cases and annual heart transplant evaluation with biopsy was equivalent among groups, but there was a greater proportion of interventional procedures performed in the postchecklist group ($P = 0.05$). Types of intervention were equivalent with the exception of pulmonary balloon valvuloplasty, which was more common in the postchecklist cohort.

Table 1. Demographic and Procedural Characteristics

	Prechecklist (n = 371)	Postchecklist (n = 370)	*P* value
Patient characteristics			
Age			
Neonate	13 (3.5%)	16 (4.3%)	0.28
Infant	56 (15.1%)	53 (14.3%)	
Children	272 (73.3%)	256 (69.2%)	
Adults (>18 years)	30 (8.1%)	45 (12.2%)	
Median age (years)	4.65 (0.1–66.9)	5.58 (0.1–68.7)	0.56
Gender			
Male	190 (51.2%)	170 (45.9%)	0.15
Female	181 (48.8%)	200 (54.1%)	
Admission type			
Inpatient	49 (13.2%)	57 (15.4%)	0.37
Outpatient	322 (86.8%)	313 (84.6%)	
Sedation			
General	269 (72.5%)	353 (95.4%)	<0.001
Conscious sedation	102 (27.5%)	17 (4.6%)	
Median procedure time (mins)	58.0 (5.0–292.0)	60.4 (3.1–271.0)	0.31
Median fluoroscopy time (mins)	9.0 (0.5–73.0)	10 (0.5–132.0)	0.63
Total complications, n (%)	13 (3.5)	8 (2.2)	0.38
Median complication severity (1–5)	2.0 (1.0–3.0)	3.0 (1.0–4.0)	**0.05**
Complication level 3–5, n (%)	7 (53.8)	8 (100)	**0.02**
Case type, n (%)			
Heart transplant	128 (34.5)	117 (31.6)	0.44
Diagnostic	126 (34.0)	111 (30.0)	0.25
Interventional	117 (31.5)	142 (38.4)	0.05
ASD/PFO closure	21 (5.7)	22 (5.9)	0.87
PDA closure	16 (4.3)	17 (4.6)	0.85
Coarctation of aorta (balloon/stent)	14 (3.8)	16 (4.3)	0.70
Pulmonary balloon valvuloplasty	4 (1.1)	12 (3.2)	0.04
Aortic balloon valvuloplasty	5 (1.3)	8 (2.2)	0.40
Angioplasty	22 (5.9)	24 (6.5)	0.75
Stent angioplasty	24 (6.5)	22 (5.9)	0.77
Coil	15 (4.0)	22 (5.9)	0.23

ASD/PFO, atrial septal defect/patent foramen ovale; PDA, patent ductus arteriosus.

Complication rates were similar between groups, but the median complication severity and percentage of levels 3–5 severity complications was significantly higher in the postchecklist cohort (Table 1). Adverse event severity in the prechecklist group (n = 13) was divided into level 3 (n = 7), level 2 (n = 2), and level 1 (n = 4), Table 2. Arrhythmias were noted in seven cases, whereas there was one case each of: arterial thrombosis requiring heparin, difficult conscious sedation requiring conversion to general anesthesia, excessive blood loss requiring transfusion, prolonged bleeding after procedure, antibiotics not given with stent placement, and large sheath inadvertently placed in femoral artery. Adverse event severity in the postchecklist group (n = 8) consisted of only level 4 (n = 1) and level 3 (n = 7) complications. Arrhythmia was present in three cases; there were two cases of systemic coil embolization, and there was one case each of: arterial thrombosis requiring heparin, excessive blood loss requiring transfusion, and prolonged bleeding after catheterization. There were no deaths or level 5 complications during the study period.

Survey Responses

Anesthesia staff completed 26 surveys prechecklist and 19 surveys postchecklist, whereas the CCL staff completed 15 and 13 surveys, respectively. With the prechecklist, there were five responses from radiology technologists, eight from nurses, 13 from anesthesia residents, two from cardiac anesthesia fellows, 11 from attending anesthesiologists, and two from pediatric cardiologists. The postchecklist consisted of three responses from radiology technologists, 10 from nurses, 11 from anesthesia residents, three from cardiac anesthesia fellows, and five from attending anesthesiologists.

There were no significant differences in safety or team attitudes within groups after introduction of the checklist, but there were several differences in opinion between groups (Table 3). Questions designed to evaluate attitude with regard to teamwork revealed that the CCL staff perceived more open communication and a greater sense of morale when compared with anesthesia staff. In addition, CCL staff strongly felt the attending cardiologist should be in charge of the cardiac laboratory during the procedure and that they received

Table 2. Reported Adverse Events

Adverse Event	Severity Score
Prechecklist (n = 13)	
Bradycardia requiring medication	3
Excessive blood loss requiring transfusion	3
Arrhythmia and hypotension during valvuloplasty	3
ST changes during IVUS – >resolved with nitroglycerin	3
CHB with catheter manipulation	3
Arterial thrombosis treated with heparin drip	3
Difficult conscious sedation requiring conversion to GA	3
ST changes during IVUS that self-resolved	2
SVT during case that self-resolved	2
Antibiotics not given with stent placement	1
Prolonged bleeding after procedure	1
8 French sheath inadvertently placed in femoral artery	1
Transient ST segment changes	1
Postchecklist (n = 8)	
Ventricular fibrillation requiring cardioversion	4
CHB with catheter manipulation	3
Prolonged oozing after procedure treated with protamine	3
Systemic embolization of coil	3
Arterial thrombosis treated with heparin drip	3
ST segment changes and arrhythmia after air embolus from defective catheter	3
Excessive blood loss requiring transfusion	3
Systemic embolization of coil	3

CHB, complete heart block; CPR, cardiopulmonary resuscitation; GA, general anesthesia; IVUS, intravascular ultrasound; SVT, supraventricular tachycardia.

appropriate feedback about their performance as compared with anesthesia staff. When overall team and safety climate attitudes were evaluated, there was no significant change within groups over the study period (Table 4). Overall perception of teamwork differed significantly between anesthesia and CCL staff ($P < 0.05$), and overall safety attitudes also trended toward significance between groups ($P = 0.052$). There was no significant interaction effect over time between groups.

Discussion

A preprocedure checklist for congenital cardiac catheterization cases is easy to perform and serves to update CCL staff. Complication rates did not significantly change after introduction of the checklist. Surveys of CCL and anesthesia staff revealed different perceptions toward ease of communication and team and safety climate within the laboratory. There were no significant changes in overall team and safety attitudes within each group after introduction of the checklist.

Checklists have previously been shown to reduce morbidity and mortality in the surgical arena.[1,4,6,8] Although our study did not demonstrate a significant reduction in the complication rate after initiation of the checklist, the total number of complications did decrease. The patient in the prechecklist group that did not receive antibiotics after stent placement may have received antibiotics if the checklist had been in place for that case. In addition, the patient that was emergently converted from conscious sedation to general anesthesia may have been identified as requiring general anesthesia preprocedure if the checklist had been utilized. There were no deaths in our study population, and our complication rate was slightly lower than previously reported literature, which may be attributed to the proportion of posttransplant routine biopsy patients, the retrospective nature of the study, or that pediatric cardiology fellows do not participate in cardiac catheterizations at our institution.[11,12] While complication rates did not significantly change after introduction of the checklist, the median complication severity and proportion of complications with severity levels 3–4 did increase. This change in adverse event severity may be secondary to the greater proportion of interventional cases performed in the postchecklist cohort or improved capture of adverse events. Larger, multicenter studies will probably be necessary to adequately answer this question.

Utilization of a preprocedure checklist also has the potential benefit of saving money while improving quality of care. Decision analysis has shown that a surgical checklist generates savings once it prevents at least five major complications if the baseline complication rate is at least 3% after surgery.[5] Although major complications are fairly rare in pediatric cardiac catheterization procedures, over time, the reduction of unscheduled admissions or emergent surgery may lead to quantifiable cost reduction. In addition, up to one-third of accepted surgical malpractice claims may have been intercepted and prevented by usage of a comprehensive surgical safety checklist.[2]

Anesthesia and CCL staff demonstrated significant differences in attitudes toward safety and teamwork. Specific survey questions that emphasize these distinctions include: "the cardiologist and anesthetist maintain open channels of communication throughout the procedure," "the attending cardiologist should be formally in charge of the cardiac laboratory during the catheterization," "in our PCCL, it is difficult to speak up if I perceive a problem with patient care," and "I have a good understanding of the patient's heart

Table 3. Mean ± Standard Deviation of Safety and Teamwork Attitude Survey

Question	Anesthesia		PCCL Staff		Between group	Within group	
Team Climate Questions	Pre (n = 26)	Post (n = 19)	Pre (n = 15)	Post (n = 13)	*P* value	*P* value	Interaction
In our PCCL, it is difficult to speak up if I perceive a problem with patient care	1.96 ± 0.87	1.50 ± 0.67	1.53 ± 0.51	1.77 ± 0.62	<0.05*	0.89	0.96
The cardiologist and anesthetist maintain open channels of communication throughout the procedure	3.54 ± 0.91	3.58 ± 0.69	3.93 ± 0.59	4.33 ± 0.49	<0.01*	0.23	0.32
Nurse or technologist input about patient care is well received in the PCCL	3.80 ± 0.71	3.89 ± 0.57	4.20 ± 0.56	3.92 ± 0.49	0.15	0.54	0.21
It is easy for the PCCL staff to ask questions when there is something they do not understand	3.65 ± 0.63	3.74 ± 0.45	4.07 ± 0.79	3.77 ± 0.72	0.16	0.50	0.23
Morale in our PCCL is high	3.50 ± 0.65	3.68 ± 0.58	3.87 ± 0.52	4.00 ± 0.71	<0.05*	0.29	0.87
Disagreements in the PCCL are appropriately resolved (i.e., what is best for the patient)	3.52 ± 0.65	3.68 ± 0.58	3.73 ± 0.70	4.00 ± 0.58	0.09	0.17	0.74
Senior staff encourages questions from junior medical and nonmedical staff during procedures in the PCCL	3.12 ± 0.73	3.11 ± 0.74	3.20 ± 1.01	3.42 ± 0.79	0.33	0.61	0.56
I am frequently unable to express disagreement with the cardiology attendings in our PCCL	2.38 ± 0.77	2.15 ± 0.99	2.21 ± 0.98	2.25 ± 0.80	0.43	0.77	0.99
PCCL staff is briefed before procedures	3.00 ± 0.94	3.11 ± 0.74	3.21 ± 0.89	4.00 ± 1.16	<0.05*	0.053	0.14
Safety Climate Questions	Anesthesia		PCCL Staff				
Debriefing after errors occur is common	2.92 ± 0.81	2.89 ± 0.46	3.07 ± 0.80	2.77 ± 1.01	0.96	0.40	0.47
The environment in our PCCL makes it easy to learn from mistakes of others	3.23 ± 0.86	3.05 ± 0.85	3.60 ± 0.83	3.46 ± 0.78	0.06	0.44	0.92
I receive appropriate feedback about my performance	3.23 ± 0.91	2.68 ± 0.82	3.67 ± 0.90	3.77 ± 0.60	<0.001#	0.28	0.11
The attending cardiologist should be formally in charge of the cardiac laboratory during the cardiac catheterization	3.69 ± 0.84	3.37 ± 1.07	4.67 ± 0.62	4.31 ± 0.63	<0.001#	0.10	0.93
Effective coordination of cardiac catheterization laboratory staff requires that the personalities of others be taken into account	3.69 ± 0.47	3.95 ± 0.62	3.53 ± 1.30	3.69 ± 1.03	0.31	0.31	0.82
It is difficult to discuss mistakes when they occur in the PCCL	2.76 ± 0.83	2.63 ± 0.68	2.53 ± 0.74	2.69 ± 0.95	0.67	0.94	0.46
PCCL staff should not question decisions made by cardiology attendings	2.08 ± 0.70	1.95 ± 0.62	2.27 ± 0.96	2.00 ± 0.82	0.52	0.29	0.72
I have a good understanding of the patient's heart condition in the PCCL	4.00 ± 0.69	4.05 ± 0.71	3.20 ± 0.86	3.08 ± 0.76	<0.001#	0.85	0.63
I have a good understanding of the critical part(s) of a procedure in the PCCL	3.68 ± 0.90	3.63 ± 0.76	3.93 ± 0.46	3.77 ± 0.93	0.32	0.59	0.77
I have a good understanding of potential complications in the PCCL	4.04 ± 0.74	3.95 ± 0.62	4.13 ± 0.83	4.15 ± 0.80	0.41	0.84	0.75

PCCL, Pediatric Cardiac Catheterization Laboratory; Likert scale: 1 = disagree strongly, 2 = disagree, 3 = neutral, 4 = agree, 5 = agree strongly.
*$P < 0.05$
#$P < 0.001$

Table 4. Teamwork and Safety Attitude Domain by Specialty

Team Climate	Pre	Post	Between Group *P* Value	Within Group *P* Value	Interaction
Anesthesia	3.17 ± 0.33	3.23 ± 0.23	<0.05*	0.23	0.68
PCCL Staff	3.54 ± 0.91	3.58 ± 0.69			
Safety Climate					
Anesthesia	3.34 ± 0.34	3.22 ± 0.19	0.052	0.13	0.82
PCCL Staff	3.46 ± 0.32	3.37 ± 0.25			

PCCL, Pediatric Cardiac Catheterization Laboratory. *$P < 0.05$.

condition in the PCCL." These questions highlight the underlying differences inherent to various subspecialists that come together to support patient care. It is noteworthy the CCL staff believes the cardiologist should be in charge of the cardiac laboratory and that open channels of communication exist between different services, whereas anesthesia staff is more neutral with respect to these factors.

Our study is the first qualitative description of attitudes toward safety and team for interventionalists and anesthesiologists in the cardiac catheterization arena. As more and more pediatric CCLs move toward a system where sedation and anesthesia are provided by a dedicated anesthesia staff, identifying and understanding the differences in opinions and attitude between these two groups is tantamount to providing optimal care. It stands to reason the best patient outcomes result from health care providers with a cohesive and strong sense of team combined with similar attitudes toward safety.

The checklist was designed to be a platform for the CCL, allowing operators to add supplemental sections such as pertinent patient history or potential complications as each individual case or operator dictated. Since its inception, we have added a rhythm check, previous access issues, and evaluation of endotracheal tube position at the beginning of the case to the preprocedure checklist. Additional elements could also include: patient diagnosis, previous surgical/interventional history, hemodynamic status, coagulation profile, previous radiation exposure, home medications, presence of pacemaker or device, or anticipated need for unusual equipment. Although this version of the checklist is a fairly minimal one, a more comprehensive one is being developed by the Society of Cardiovascular Angiography and Interventions as part of the Quality Improvement Toolkit and should be available in the near future. The optimal checklist will probably be tailored to each individual institution, but these examples can provide a blueprint to facilitate its incorporation into everyday practice.

The major shortcomings of this study are the retrospective nature and smaller sample size. Measures of hemodynamic vulnerability, which have previously been associated with adverse outcomes, were not analyzed for the purposes of this study.[9] Changes in anesthesia staffing may also have introduced bias into the study. Individual responses to survey questions were not tracked after implementation of the checklist. Additionally, staff perceptions of attitude, safety, or communication may vary depending on who is the primary operator.

In conclusion, a preprocedure checklist for cardiac catheterization cases is easy to perform and improves staff perception of being briefed. Anesthesia and CCL staff differed in attitudes regarding safety and teamwork. Further studies are required to determine if this briefing could lead to better communication among services and reduce the number and severity of complications.

Author Contributions

Brent M. Gordon, MD: Concept/design, data analysis/interpretation, drafting article, and critical revision of article.

Teresa Lam, MD: Data collection and critical revision of article.

Khaled Bahjri, MD: Statistics and data analysis/interpretation.

Aijaz Hashmi, MD: Concept/design and critical revision of article.

Micheal A. Kuhn, MD: Concept/design and critical revision of article.

Corresponding Author: Brent M. Gordon, MD, Division of Pediatric Cardiology, Loma Linda University Medical Center, MC-4433, PO Box 2000, 11234 Anderson Street, Loma Linda, CA 92354-0200, USA. Tel: (909) 558-4711; Fax: (909) 558-0311; E-mail: brgordon@llu.edu

Conflict of interest: None for any authors.

Disclosures: None to report for any authors.

Accepted in final form: May 6, 2013.

References

1 Ricci MA, Brumsted JR. Crew resource management: using aviation techniques to improve operating room safety. *Aviat Space Environ Med*. 2012;83:441–444.
2 de Vries EN, Eikens-Jansen MP, Hamersma AM, Smorenburg SM, Gouma DJ, Boermeester MA. Prevention of surgical malpractice claims by use of a surgical safety checklist. *Ann Surg*. 2011;253:624–628.
3 de Vries EN, Hollmann MW, Smorenburg SM, Gouma DJ, Boermeester MA. Development and validation of the SURgical PAtient Safety System (SURPASS) checklist. *Qual Saf Health Care*. 2009;18:121–126.
4 Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med*. 2009;360:491–499.
5 Semel ME, Resch S, Haynes AB, et al. Adopting a surgical safety checklist could save money and improve the quality of care in U.S. hospitals. *Health Aff*. 2010;29:1593–1599.
6 van Klei WA, Hoff RG, van Aarnhem EE, et al. Effects of the introduction of the WHO "Surgical Safety Checklist" on in-hospital mortality: a cohort study. *Ann Surg*. 2012;255:44–49.
7 Berrisford RG, Wilson IH, Davidge M, Sanders D. Surgical time out checklist with debriefing and multidisciplinary feedback improves venous thromboembolism prophylaxis in thoracic surgery: a prospective audit. *Eur J Cardiothorac Surg*. 2012;41:1326–1329.
8 Kim SW, Maturo S, Dwyer D, et al. Interdisciplinary development and implementation of communication checklist for postoperative management of pediatric airway patients. *Otolaryngol Head Neck Surg*. 2012;146:129–134.
9 Bergersen L, Gauvreau K, Foerster SR, et al. Catheterization for Congenital Heart Disease Adjustment for Risk Method (CHARM). *JACC*. 2011;4:1037–1046.
10 Bergersen L, Gauvreau K, Marshall A, et al. Procedure-type risk categories for pediatric and congenital cardiac catheterization. *Circ Cardiovasc Interv*. 2011;4:188–194.
11 Bergersen L, Marshall A, Gauvreau K, et al. Adverse event rates in congenital cardiac catheterization—a multi-center experience. *Catheter Cardiovasc Interv*. 2010;75:389–400.
12 Vitiello R, McCrindle BW, Nykanen D, Freedom RM, Benson LN. Complications associated with pediatric cardiac catheterization. *J Am Coll Cardiol*. 1998;32:1433–1440.
13 Sexton JB, Helmreich RL, Neilands TB, et al. The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research. *BMC Health Serv Res*. 2006;6:44.

Appendix 1: Pediatric Cardiac Catheterization Checklist

Confirm all team members have introduced themselves by name and role.
Confirm the patient's name, procedure, purpose of procedure, and any planned interventions.
Is the patient going to be admitted?
Does the patient have a:
Known allergy? Yes/No
Latex allergy? Yes/No
Difficult airway or aspiration risk?
Yes/No, and equipment/assistance available
Will antibiotics be required?
Yes/No
Will Heparin be given?
Yes/No
Anticipated Critical Events
To Interventionalist:
What are the critical or non-routine steps?
How long will the case take?
Is there a potential need for blood transfusion? Has type and cross been sent?
Is there any special equipment required and, if so, has it been addressed?
To Anaesthetist:
Are there any patient-specific concerns?
To Nursing Team:
Are there patient, equipment issues, or any concerns?