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Decision making in pediatric cardiac surgery using intraoperative echo

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Routine intraoperative assessment of the quality of surgical repair in patients with congenital heart disease has been limited in the past to rather gross techniques such as oximetry or green-dye curves to evaluate residual shunts, or pressure measurements to evaluate residual stenoses. These methods can be cumbersome, time-consuming and because they are 'indirect' techniques, they may lack accuracy. Echo Doppler with color flow imaging (echo DCFI) is uniquely suited for these purposes since it provides readily available images of complex spacial anatomic arrangements as well as information about blood flow. This prospective study was conducted on the hypothesis that *routine* intraoperative use of echo DCFI would provide useful information to the surgeon that would impact significantly on the planning, conduct, and qualitative assessment of results in patients undergoing repair of complex congenital heart lesions.

Methods

Between March, 1987 and October, 1988 routine intraoperative pre and post cardiopulmonary bypass (CPB) echo DCFI was performed on 224 patients undergoing surgical procedures for the repair of congenital cardiac defects at Duke University Medical Center. The series is consecutive only in the sense that it included all patients in whom surgery was performed principally for the repair of congenital heart defects on CPB through a median sternotomy. All patients had preoperative transthoracic echo DCFI. Preoperative cardiac catheterization was performed in 190 patients (85%). Of these, 41 patients had catheterizations more than 3 months prior to operation. Thus 75 patients (34%) underwent surgery without catheterization or with a remote catheterization. Follow-up survival and reoperative data were collected for all patients. Direct contact epicardial echo DCFI examinations were performed using a Hewlett Packard HPO 77020CF color flow imaging device. The 5.0 MHz short focus transducer was used in the vast majority of cases but in certain cases a 2.5 MHz or 3.5 MHz transducer was also used. When deemed necessary epicardial scans with a non-imaging 1.9 MHz continuous wave Doppler probe was also performed. Prior to imaging, the transducer and cable were cleaned with a commercially available glutaraldehyde solution and then wiped with sterile saline and introduced by the surgeon into a sterile sheath containing 20 ml of sterile ultrasound gel. This sheath was then secured to the surgical side of the ether screen so that it was available throughout the case. Data were routinely acquired from the epicardial surface before initiation of CPB and again at the conclusion of the procedure, usually after the patient had been weaned from CPB. In some instances, additional data were obtained during periods of rewarming with the patient still on CPB. Studies included complete interrogation of all cardiac chambers and valves, including venous inflows and great vessel outflows. All data were recorded on high-fidelity video tape for later review. At the conclusion of each case, a detailed questionnaire with over 200 queries concerning diagnosis and outcome as well as how the echo DCFI study influenced planning and conduct of the surgical procedure was completed. Data from each study were then entered into a data bank for later retrieval and analysis.

Results

There were 132 males and 92 females who ranged in age from 1 day to 42 years (mean = 4.1 years). Seventy-nine (35%) were less than 1 year old and 128 (57%) were less than 3 years old. The smallest patient studied weighed 1.9 kg. Complete pre and post CPB examinations could be conducted in 219/224 cases (98%). In two patients, a pre-CPB

examination could not be completed due to severe ventricular arrhythmias in one and systemic arterial oxygen desaturation in another. In 3 patients, the post-CPB examination could not be conducted as the patients could not be weaned from cardiopulmonary bypass. The number of studies per case ranged from 1 to 7 (mean 2.73/case). The average study period for complete examination was 3.71 ± 1.78 minutes. Routine intraoperative DCFI added an average 9.93 ± 5.2 minutes to each case, most of this as non-CPB time. In all patients the quality of the intraoperative epicardial images were deemed superior to those obtained from the chest wall.

Table 1. Unsuspected findings: 52 unsuspected findings in 47 patients (21%).

Anomalies of the atrial or ventricular septum	
Atrial septal defect (none suspected)	10
Interatrial septal aneurysm	5
Multiple ventricular septal defects	5
Multiple atrial septal defects	4
Ventricular septal defect (none suspected)	2
Atrio-ventricular septal defect (complete)	1
Anomalies of ventricular inlet/outlet	
Valvular anatomic or functional anomaly	3
Left or right ventricular outflow anomaly	3
AV leaflet chordal anomaly	2
Functional flow anomaly (Tet spell)	2
Mitral systolic anterior motion	1
Anomalies of venous drainage	
Aberrant left superior vena cava	6
Others	
Found normal anatomic structures thought absent	5
Patent ductus arteriosus	2
Residual shunt (Blalock-Taussig)	1

Key: AV = atrio-ventricular valve

Table 2. Impact on case planning: echo-DCFI impacted planning 134 times in 105 patients (47%).

Influence operative plan prior to CPB	N=50 (37%)
Change diagnosis	2
Change operation	12
Repair unsuspected finding	14
Influence approach to lesion	10
Altered CPB plan	12
Guide the intraoperative approach	N=74 (55%)
Clarify valve and/or chordal commitments	24
Indicate best manner for valve repair	8
Identified precise location of defect	10
Specify how to repair septal defect or outlet	32
Alter anesthesia conduct before CPB	N=10 (8%)

Key: CPB = cardiopulmonary bypass

Intraoperative pre-CPB studies detected 52 new and unsuspected findings in 47 patients (21%) when compared to the preoperative catheterization and/or conventional chest wall echocardiographic data. The nature of these findings are summarized in Table 1. Echo DCFI results were judged helpful in planning when they contributed information that either settled preoperative uncertainty or provided data that influenced the conduct of the case prior to or during operative exploration. When used in this fashion, pre-CPB echo DCFI had an effect on operative procedures in 105/224 cases (47%) (Table 2). The ability to appreciate specific anatomic and dynamic features of the defect immediately prior to institution of CPB was often felt to be quite beneficial by the surgical team. It was observed that disclosure of previously unsuspected findings was more commonly associated with the tendency for echo DCFI to influence planning at the time of operation ($P < .001$). Following operative repair an echo DCFI study was repeated. The quality of the operative repair was assessed as acceptable or unacceptable on the basis of whether the surgeon had accomplished the stated goal. The surgeon's opinion of his satisfaction with the repair was rendered before inspection by echo DCFI. Acceptable results were found in 204 patients (91%) and included those with no evidence of a residual defect (150 patients) as well as those with postoperative echo Doppler findings (PEDF) of minor flow disturbances which were felt to be of minor significance (54 patients). Seventeen patients (6%) left the operating room with residual defects and 3 patients could not be completely evaluated after cardiopulmonary bypass. An initial unacceptable operative result was identified in 38 patients (17%). At the time of identification, the risk of further surgery was felt to be prohibitive in 8. Additional repairs, however, were attempted in 30 patients. Nineteen of these patients (63%) had further surgery solely on the basis of echo DCFI findings with no clinical evidence of residual problems and 16 of these patients left the operating room with an optimal repair. From the entire series of 224 patients, echo DCFI alone identified an unacceptable initial surgical result in 8% and thus facilitated correction at the time of initial surgery in a group of patients who might otherwise have had a suboptimal surgical result. Post bypass myocardial function was also noted and the prognostic significance of myocardial

dysfunction was evaluated over long-term follow-up. Patients were followed with respect to reoperation, complications, or death for as long as two years post surgery. Patients who left the operating room with a significant residual defect, documented by epicardial echo DCFI, had a greater likelihood of reoperation or death over the follow-up period (P<.001). Those patients with abnormal ventricular function at the conclusion of the operative procedure had a higher likelihood of early but not of late mortality (P<.001). Those patients who left the operating room with no echo DCFI findings of concern had a 90% likelihood of a long-term acceptable outcome compared to a 65% long-term acceptable outcome in those patients who had any echo DCFI findings of concern at the conclusion of the procedure.

Conclusions

When routinely employed during repair of congenital heart disease, echo DCFI impacts in over 50% of cases by disclosing previously unrecognized abnormalities, assisting planning in the operating room, or by assisting the surgeon in recognizing the presence of less than optimal results. In the latter case, echo DCFI specifies and directs immediate action for the correction of residual defects. Such methods can be employed even in very small infants. While no method can replace surgical judgement, experience or skill, intraoperative epicardial echo DCFI is a valuable tool for guiding repair of congenital heart defects as well as for the immediate assessment of operative results.