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Original Research Article

Echocardiographic assessment of right ventricular function status in children with congenital heart disease with irreversible and reversible pulmonary hypertension compared to normal children

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ABSTRACT

Background: Right ventricular (RV) dysfunction is prevalent in children with congenital heart disease (CHD), particularly in association with pulmonary hypertension (PH). Transthoracic echocardiography (TTE) is crucial for detecting, assessing severity, and monitoring CHD patients with PH. The current study aimed to compare RV function assessed by TTE between CHD patients with PH and healthy children.
Methods: The case group comprised CHD patients diagnosed with PH via TTE and confirmed by cardiac catheterization. The control group included children with normal echocardiograms. A total of 40 patients were enrolled based on predefined criteria.
Results: The study included 20 cases and 20 controls. Echocardiographic parameters revealed significant differences between the case and control groups, with increased RV dimensions in the case group, except for RV subcostal wall thickness. RV systolic function parameters, including tricuspid annular plane systolic excursion (TAPSE) and tricuspid annular systolic velocity (S'), were significantly lower in the case group. RV diastolic function parameters, including E/A ratio, E/e', and deceleration time (DT), were also significantly different between the groups. The RV global function parameter, tissue Doppler imaging-derived myocardial performance index (TD MPI), was significantly higher in the case group.
Conclusions: Echocardiographic evaluation of RV function, including TAPSE, S', TD MPI, E/A ratio, E/e', and DT, in CHD children with PH correlates with PH severity. This assessment can aid in early detection of PH severity before irreversible changes occur and serve as an alternative to right heart catheterization.

Keywords: RV function in children, Pulmonary hypertension, Transthoracic echocardiography

INTRODUCTION

Pulmonary hypertension is a relatively common complication of congenital heart disease, seen in about 10% of adult cases. The prevalence of pulmonary hypertension in congenital heart disease varies according to size and location of cardiac defect and 4-15% of patients with CHD will go on to develop pulmonary hypertension. It is defined as mean pulmonary artery pressure (mPAP) >20 mm of Hg at resting state.[1] Pulmonary hypertension characterized hemodynamically by the presence of pre capillary PH including an end-expiratory pulmonary artery wedge pressure (PAWP) ≤15 mmHg and a pulmonary vascular resistance ≥3 wood units (WU).[1] Pulmonary hypertension in CHD is commonly secondary to left- to-right shunt defects, common defects includes ventricular septal defects, atrial septal defects, persistent ductus arteriosus. It also shown that size of the defect to be influential in whether patient develop PAH and also in more complex lesion such as atrioventricular septal defects

or truncus arteriosus where PAH develop early in life.[2] So, transthoracic echocardiography remains an important tool in evaluation and management of PH, although cardiac catheterization is gold standard for confirming the diagnosis of PH.[3]

Right ventricle dysfunction is frequently seen in children with congenital heart disease particularly when associated with pulmonary hypertension. The evaluation of RV function plays a major role in detection, assessing the severity and follow-up of pulmonary hypertension.[3] Although the RV function is more difficult to evaluate than LV because of its more complex geometry, its anterior position in chest and its difficult physiology and mechanics and also the RV has triangular appearance in sagittal plane and a crescent shape in the coronal plane.[4]

In early stage of PAH, the right ventricle tends to remain adapted to afterload with increase contractility and little or no increase in right heart chamber dimensions. However, the main function of right ventricle is to pump deoxygenated blood to the lung for oxygenation. Progressive volume overload due to left to right shunt develops pulmonary hypertension leads to progressive chamber hypertrophy. The adaptive response of myocardial hypertrophy is followed by progressive contractile dysfunction.[5]

As contractile weakening progresses, clinical evidence of decompensated right ventricular failure occurs, characterized by rising filling pressures, diastolic dysfunction, and diminishing cardiac output, which is compounded by tricuspid regurgitation due to annular dilatation and poor leaflet coaptation. The increased size and pressure overload of the right ventricle also produce diastolic dysfunction of the left ventricle.[6]

Echocardiographic assessment of RV size can be estimated by measuring right ventricular basal diameter, longitudinal dimension, subcostal wall thickness, right ventricular outflow tract parasternal short axis distal diameter, RVOT parasternal long axis proximal diameter. RV systolic function by tricuspid annular plane systolic excursion (TAPSE), tricuspid annular systolic velocity (S'). RV diastolic function can be estimated by measuring early diastolic tricuspid valve inflow/late diastolic tricuspid valve inflow (E/A); early diastolic tricuspid valve inflow/early diastolic tricuspid annular velocity (E/e′); DT is deceleration time and global RV function parameter, myocardial perfusion index (MPI) indicates both systolic and diastolic function. However, cardiac catheterization is gold standard for confirming pulmonary hypertension, so during cardiac catheterization, pulmonary artery pressure, right atrium pressure, left atrium pressure or pulmonary artery wedge pressure is taken and also pulmonary and systemic flows is measured by the Fick method using oxygen consumption and oxygen content derived from oxygen saturation.[7]

The PVR is calculated as the ratio of the difference between mean pulmonary artery pressure and mean left atrium pressure or pulmonary artery wedge pressure to pulmonary blood flow (Qp). Suspecting high PVR patient undergone Vasoreactivity test with 100% oxygen for 10 min, and PVR is considered significant if the mean pulmonary artery pressure falls by (≥20%), or calculated PVRI is less than 6 WU/m² or PVR/SVR ≤0.3. Thus, this study intends to assess the RV function by TTE and compare that to healthy control, so that strict measures can be taken before the irreversible changes occurs in patient of congenital heart disease with pulmonary hypertension.

METHODS

It is case control study. The study was conducted at the Department of Pediatric Cardiology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh. The study was conducted during the period of July 2021 to June 2022.The patients who were diagnosed as pulmonary hypertension by transthoracic echocardiography and confirmed by cardiac catheterization were included as case group and control group were selected from patients with normal echocardiogram and clinically indicated for evaluation of presence of murmurs, chest pain, palpitation or syncope. In patients with pulmonary hypertension right ventricular function were measured with a Vivid- S70N echocardiography machine (GE Vingmed, Horten, Norway). Right ventricular global function was measured by myocardial performance index (RVMPI), the tricuspid valve systolic flow velocity (S'), the tricuspid annular plane systolic excursion (TAPSE) and diastolic function (E/A, E/e', DT).

Study population

All congenital heart disease patients less than 18 years of age of both male and female with pulmonary hypertension diagnosed by TTE and confirmed by cardiac catheterization (as case), and healthy children who were evaluated for presence of murmurs, chest pain, palpitation or syncope (as control group), at Department of Paediatric Cardiology, BSMMU.

Inclusion criteria

All the patients less than 18 years of age of both male and female with congenital heart disease and pulmonary hypertension diagnosed by TTE and confirmed by cardiac catheterization (as case) and structurally normal heart with H/O palpitation, chest pain, syncope (as control group) presented at paediatric cardiology department, BSMMU were included in this study.

Exclusion criteria

Patients with idiopathic pulmonary hypertension, familial pulmonary hypertension, evidence of any systemic or lung disease, and parents unwilling to participate in the study were excluded.

Study procedure

Patients with congenital heart disease with pulmonary hypertension detected by TTE and confirmed by cardiac catheterization were enrolled as case group and normal healthy children who visited the OPD of pediatric cardiology department, BSMMU were included as control group in the study. Before sampling, written consent was taken after explaining the steps and purpose of the study. At first their demographic characteristics were recorded. Subjects were examined clinically and conventional 2D, color Doppler and tissue Doppler Echo was done.

Echocardiographic evaluation was performed with a Vivid- S70N echocardiography machine (GE Vingmed, Horten, Norway). Measurements were taken according to the American Society of echocardiography recommendations.[8] At first RV basal diameter, RV longitudinal dimension, RV subcostal wall thickness, right ventricular outflow tract (RVOT), parasternal short axis (PSAX) distal diameter, right ventricular outflow tract (RVOT), parasternal long axis (PLAX) proximal diameter was measured, then RV global function was assessed by myocardial performance index (MPI). RV systolic function was estimated by tricuspid annular plane systolic excursion (TAPSE), tricuspid annular systolic velocity (S'). RV diastolic function was assessed by early diastolic tricuspid valve inflow/late diastolic tricuspid valve inflow (E/A), early diastolic tricuspid valve inflow/early diastolic tricuspid annular velocity (E/e'), and deceleration time (DT). Images were digitally stored and analyzed offline at the end of each study. Then quantitative RV functions were compared between the case and control groups. Cardiac catheterization was done for the cases after appropriate sedation; mean pulmonary artery pressure was measured to confirm pulmonary hypertension.

Statistical analysis

Data were recorded on a predesigned format and managed using Microsoft excel 2013 (Microsoft Corporation, Redmond, WA, USA). All the entries were double-checked for any possible error. Descriptive statistics like mean and standard deviation for quantitative variables and numbers with percentages for categorical variables were calculated. Unpaired student's t-test was performed to test the significant difference between pre- and post-procedural variables. All the statistical analysis was performed with the help of statistical package for social sciences (SPSS) version 22.0 (IBM Corp., Armonk, NY, USA). A p value of ≤0.05 was considered significant.

RESULTS

Table 1 shows demographic data of study population. Mean age for the case group was 51.7±59.3 month and 61.4±34.2 in control group while mean weight and mean height were 17.1±12.6 kg and 104.7±26.3 cm in case group and mean weight 17.4±8.5, mean height 104.3±19.9 respectively in control group. Mean body surface area was calculated as 0.66±0.35 m^2 and 0.69±0.22 m^2 respectively in case and control group. All these demographic data resemble no statistical difference between case and control group. Among case group 50% population was male while 45% male in control group. Meanwhile 55% hailing from urban area in case group and 60% in control group respectively. All these demographic data resemble no statistical difference between case and control group.

Table 1: Demographic data of study population (n=40).

Variables	Case (n=20)	Control (n=20)	P value*
Age (month)	51.7±59.3	61.4±34.2	0.5
Weight (kg)	17.1±12.6	17.4±8.5	0.9
Height (cm)	104.7±26.3	104.3±19.9	1
BSA (m^2)	0.66±0.35	0.69±0.22	0.7
Sex (male)	50% (10)	45% (9)	0.7
Residence (urban)	55% (11)	60% (12)	0.7

Data was expressed as mean±SD, unpaired t test was done as a test of significance, *p value <0.05 was considered statistically significant, BSA=body surface area

Figure 1 shows that, among case group VSD was more common (35%), followed by PDA (30%), ASD (20%), AVSD (10%) and TAPVC (5%).

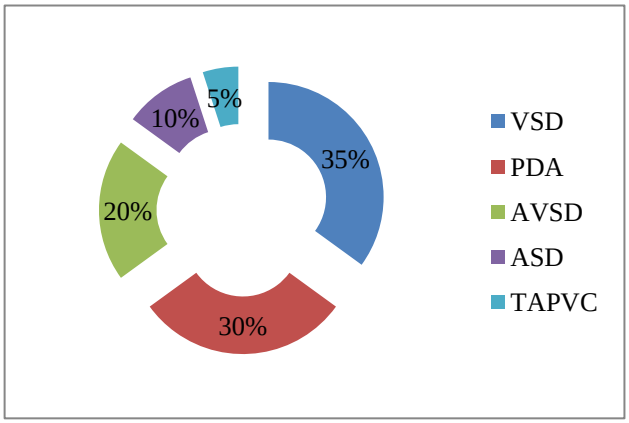

Figure 1: Disease distribution among case group (n=20).

Table 2 shows different clinical presentation of study population. Among case group majority of patients presented with H/O recurrent RTI (80%) followed by feeding difficulty (75%) and dyspnea (75%). In control group H/O RTI (40%) followed by feeding difficulty (35%) and dyspnea (20%). All these clinical presentation data resembles statistically significant between case and control group. The mean heart rate for case group was 108.3±11.6 beat/min and control group was 97.9±25.7 beat/min. Mean SpO_2 measured by Pulse oximeter was 95.4±2.43% and 97.4±0.7 respectively. Among both variable mean SpO_2 was statistically significant in both case and control group.

Table 2: Clinical presentation and examination findings in study population (n=40).

Variables	Case (n=20)	Control (n=20)	P value*
H/O recurrent RTI	80% (16)	40% (8)	0.009
Feeding difficulty	75% (15)	35% (7)	0.01
Dyspnea	75% (15)	20% (4)	0.0004
SpO_2 (%)	95.4±2.43	97.4±0.7	0.001
Heart rate (b/m)	108.3±11.6	97.9±25.7	0.1

Data was expressed as mean±SD, unpaired t test was done as a test of significance, *p value <0.05 was considered statistically significant

Figure 2 shows grading of severity of pulmonary Hypertension mild 20%, moderate 35% and severe 45% respectively in case group.

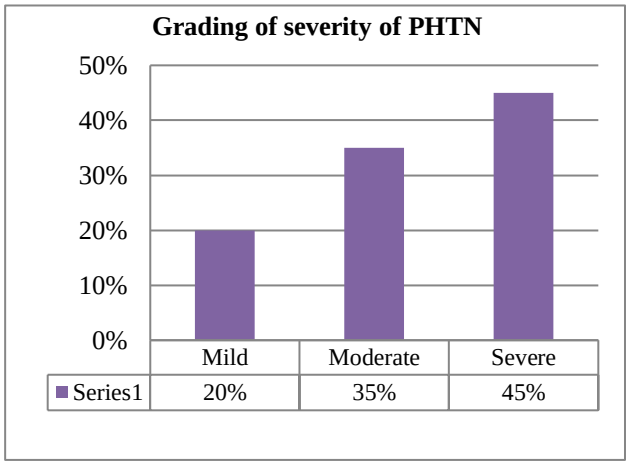

Figure 2: Grading of severity of PHTN in case group (n=20).

Table 3 shows mean RV basal diameter 27.4±6.6 mm, RV major dimension 36.6±9.6 mm RV subcostal wall thickness 4.7±0.25 mm, RVOT PSAX distal diameter 23.4±5.3 mm, RVOT PLAX proximal diameter 17.4±3.2 mm respectively in case group and subsequently 24.1±2.7, 31.5±5.7, 4.7±0.4, 20.4±2.92, 14.9±3.8 in control group. All the chamber dimensions were significantly increased in case group except the RV subcostal wall thickness compared to control group.

Table 4 shows RV systolic function parameters mean TAPSE 17.1±2.13, mean tricuspid annular systolic velocity (S') 10.5±1.17 in case group and subsequently 18.5±0.9, 11.2±0. 49 in control group. Both these parameters were statistically significant between case and control group. In terms of RV diastolic function parameters mean E/A ratio 1.4±0.42, mean E/e′ 5.5±0.38 and mean DT 120.3±4.93 respectively in case group and subsequently mean 1.7±0.15, 5.2±0.25 and 127.7±2.53 in control group. All these parameters were statistically significant in case and control group. In terms of RV global function parameter mean PD MPI 0.39±0.04 in case group and mean PD MPI 0.35±0.02 in control group and mean TD MPI 0.49±0.07 mean 0.45±0.04 in case and control group respectively. All these parameters were statistically significant in case and control group.

Table 3: Comparison of chamber dimension between case (n=20) and control (n=20) group.

Variables	Case (n=20)	Control (n=20)	P value*
RV basal diameter (mm)	27.4±6.6	24.1±2.7	0.04
RV major dimension (mm)	36.6±9.6	31.5±5.7	0.04
RV subcostal wall thickness (mm)	4.7±0.25	4.7±0.4	1.00
RVOT PSAX distal diameter (mm)	23.4±5.3	20.4±2.92	0.03
RVOT PLAX proximal diameter (mm)	17.4±3.2	14.9±3.8	0.03

Data was expressed as mean±SD, unpaired t test was done as a test of significance, *p value <0.05 was considered statistically significant

Table 4: Comparison of RV systolic, diastolic and global function between case (n=20) and control (n=20) group.

Variables	Case (n=20)	Control (n=20)	P value*
RV systolic function			
TAPSE (mm)	17.1±2.13	18.5±0.9	0.01
S' (cm/s)	10.5±1.17	11.2±0.49	0.02
RV diastolic function			
E/A ratio	1.4±0.42	1.7±0.15	0.004
E/e'	5.5±0.38	5.2±0.25	0.005
DT (ms)	120.3±4.93	127.7±2.53	0.0001
RV global function			
PD MPI	0.39±0.04	0.35±0.02	0.0003
TD MPI	0.49±0.07	0.45±0.04	0.03

Data was expressed as mean±SD, unpaired t test was done as a test of significance, *p value <0.05 was considered statistically significant

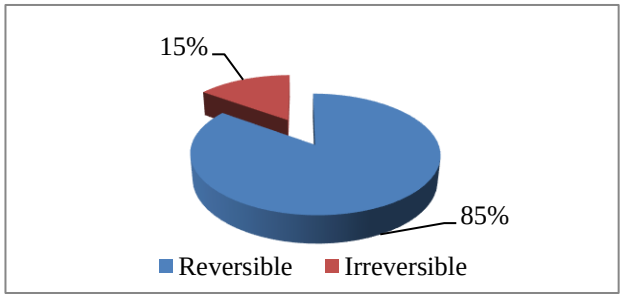

Figure 3: Distribution of pulmonary hypertension as reversible (n=17) and irreversible (n=3) in case group (n=20).

Table 5: Comparison of RV function between reversible (n=17) and irreversible (n=3) group.

Variables	Reversible (n=17)	Irreversible (n=3)	P value*
TAPSE (mm)	17.8±1.93	14.6±0.47	0.0001
E/e′	5.3±0.37	6±0.14	0.0001
DT (ms)	121.1±4.9	116±1.4	0.0001
TD MPI	0.47±0.07	0.56±0.02	0.0001

Data was expressed as mean±SD, unpaired t test was done as a test of significance, *p value <0.05 was considered statistically significant

Table 5 shows comparison of RV function between reversible and irreversible group mean TAPSE 17.8±1.93, mean E/e′ 5.3±0.37, mean DT 121.1±4.9 and mean TD MPI 0.47±0.07 in reversible group and mean TAPSE 14.6±0.47, mean E/e′ 6±0.14, mean DT 116.1±1.4 and mean TD MPI 0.56±0.02 respectively in irreversible group. All these comparisons were statistically significant.

DISCUSSION

Right ventricular failure is a significant cause of morbidity and mortality in patients with congenital heart disease with pulmonary hypertension. Transthoracic echocardiography is an important tool in the evaluation of patients with PH for early diagnosis and early intervention. So, this study is designed to detect right ventricular dysfunction at an early time before the irreversible changes occurs in patient of congenital heart disease with pulmonary hypertension.

This case control study was conducted in paediatric cardiology department, BSMMU with total sample size of 40 including 20 children of congenital heart disease with pulmonary hypertension diagnosed by transthoracic echocardiography and confirmed by cardiac catheterization as case group and 20 healthy children as control group.

Mean age for the study group was 51.7±59.3 month while mean weight and mean height was 17.1±12.6 kg and 104.7±26.3 cm respectively. Mean body surface area was calculated as 0.66±0.35 m^2. Most of the study subject of case (55%) and control (45%) group came from urban area. Sex distribution in case group showed equal percentage whereas control group showed more female (55%) than male (45%). Similar study was done by Cevik et al. They compare 70 children among 30 patient group mean age 77.6±93.2 and 40 control group mean age 77.6±64.8 respectively. The mean of height lower in case (99.9±43.6) compared to control (105.5±34.7) group. Among case group 53.3% were female whereas 46.7% were male and control group showed equal percentage of sex distribution.[9]

Majority patients presented with H/O recurrent RTI (80%) followed by feeding difficulty (75%) and dyspnoea (75%) in case group which was particularly evident in children belongs to lower age group whereas H/O recurrent RTI (40%), feeding difficulty (35%), dyspnoea (35%) which was lower in control group and these finding was similar in many CHD described by many authors. Mean SpO_2 measured by pulse oximeter was 95.4±2.43% and mean heart rate 108.3±11.6 beat/min in case group whereas mean SpO_2 measured by Pulse oximeter was 97.4±0.7% and mean heart rate 97.9±25.7 beat/min respectively in control group. These findings are similar to the clinical examination described by many authors in CHD and healthy population. In distribution of diseases in study population VSD was more common (35%) followed by PDA (30%), ASD (20%), AVSD (10%), and TAPVC (5%). Similar study was done by Friesen et al which showed VSD was more common followed by ASD, PDA, AVSD, PAPVR.[10]

RV systolic function parameter mean TAPSE was 17.1±2.13 in case group whereas mean TAPSE was 18.5±0.9 in control group. In study population TAPSE 17 mm or less identified the patient with pulmonary hypertension who had more advanced RV dysfunction as compared with a TAPSE 18 mm or greater in control group. Thus, our result suggests that TAPSE was a robust measure of RV function and a powerful predictor of patient survival in pulmonary hypertension. Mean tricuspid annular systolic velocity S′ was 10.5±1.17 and S′ 11.2±0.49 respectively in case and control group which showed less impact on RV function in patient with pulmonary hypertension. Similar study done by Forfia et al which showed TAPSE was a highly specific indicator of depressed RV function. TAPSE 18 mm or less having direct impact on RV function and pulmonary artery hypertension. Patient with TAPSE less than 18 mm had significantly reduced systolic function and high PVR comparison to patient with TAPSE 18 mm or greater. So, TAPSE correlated inversely with PVR and poor RV systolic function.[11]

The RV diastolic function parameters mean E/A ratio was 1.4±0.42, mean E/e′ 5.5±0.38 and mean DT 120.3±4.93 respectively in case group and subsequently mean E/A ratio was 1.7±0.15, mean E/e′ 5.2±0.25 and DT 127.7±2.53 in control group. It was challenging to assess RV diastolic dysfunction but it may be important for grading of disease severity, patient management and prognosis although these parameters were statistically significant between case and control group. A study done by Okumura et al recommended that assessment of RV diastolic function in children with PAH is challenging, although it does not differentiate between early versus late diastolic abnormalities.[12]

The RV global function parameter mean PD MPI was 0.39±0.04 and 0.35±0.02 and mean TD MPI was 0.49±0.07 and 0.45±0.04 in case and control group respectively. MPI value assessed by conventional pulse wave Doppler and tissue Doppler showed that TD-MPI was more favorable for estimation of MPI because it allows simultaneous measurement of both diastolic and systolic intervals in the same cardiac cycle whereas PD-

MPI measures time intervals based on flow velocity curves and performed in different cardiac cycle.[13]

In our study RV TDI-MPI was significantly elevated in children with PH, so it was used as marker for RV dysfunction in children with PH where common echocardiographic marker for PH, TR jet often difficult to obtain. Similar study done by Friesen et al, which shows children with PH had significantly increased RV TDI-MPI (0.49 versus 0.35, p<0.0001) compared to control group.

It was easily measured over one cardiac cycle, independent of heart rate and ventricular geometry can be useful measurement for determining ventricular dysfunction in children with PH by non- invasive measurement and increase in RV TDI- MPI may suggest decrease in ventricular dysfunction, increase in mPAP and PVR.[10]

In this study group, 17 (85%) were develop reversible PH whereas 3 (15%) had irreversible PH and comparison of RV function between reversible and irreversible group, mean TAPSE 17.8±1.93, mean E/e′ 5.3±0.37, mean DT 121.1±4.9 and mean TD MPI 0.47±0.07 in reversible group whereas mean TAPSE 14.6±0.47, mean E/e′ 6±0.14, mean DT 116.1±1.4 and mean TD MPI 0.56±0.02 respectively in irreversible group. All these comparisons were statistically significant. So, study reflect on following above echocardiographic parameters uses as early detection of severity of PH before going to irreversible changes.

Limitations

The sedation conditions at the time of echocardiography and cardiac catheterization were different. Cardiac catheterization was an invasive procedure so, difficult to perform in children. It was difficult to obtain proper view during echocardiography in some children.

CONCLUSION

Echo evaluation of RV function included TAPSE, S′, TDI - MPI, E/A ratio, E/e′ and DT in children with congenital heart disease with pulmonary hypertension correlates with the severity of pulmonary hypertension which can be used for early detection of severity of pulmonary artery hypertension before going to irreversible changes and also as an alternative to right heart catheterization.

Recommendations

With this study result, it is recommendable that echocardiographic parameter TAPSE, S′, TDI-MPI can be used as tool for assessment of RV function in children having CHD with PH which correlates with the severity of PH before the irreversible changes occur. It is also recommended that a multi-centered study should be carried out with large sample size, and routine practice of RV functional assessment should be done while dealing with CHD with PH.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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