Bedside ultrasonography screening for congenital renal anomalies in children with congenital heart diseases undergoing cardiac repair

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Introduction: Ultrasound (US) assessment of renal anomalies in children requiring pediatric cardiac surgery is not a standard practice. This study is highlighting the role of bedside US performed by intensivist to detect occult renal anomalies associated with congenital heart disease (CHD).

Methods: A cross sectional study for 100 consecutive children with CHD admitted to Pediatric Cardiac Intensive Care Unit (PCICU) in 2015. US of kidneys screening was performed by trained pediatric cardiac intensivists to ascertain the presence of both kidneys in renal fossae without gross anomalies and to investigate if early detection of occult kidney anomaly would have any impact on outcome.

Results: After screening of 100 consecutive children with CHD with renal US, we identified in 94 cases (94%) normal right and left kidney in the standard sonographer shape within the renal fossae. In 6 cases further investigation revealed ectopic kidney in 3 patients (50%), solitary functional kidney in 2 patients (33%) and bilateral grade IV hydronephrosis in one patient (17%). Urinary tract infection developed peri-operatively in 66% of the cases with kidney anomalies with statistical significance compared to patients with normal renal US *(P: 0.0011)*. No significant renal impairment was noted in these patients post-surgery. We observed no specific association between the type of renal anomaly and specific CHD.

Conclusion: Routine renal US in children with CHD demonstrated prevalence of associated congenital renal anomalies in 6% of children undergoing cardiac surgery. The presence of occult renal anomalies was associated with higher UTI risk. Performing routine renal US as a standard practice in children with CHD is justifiable.

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Introduction

Congenital heart disease (CHD) is the most common congenital disorder in newborns with a reported prevalence of 6 to 13 per 1000 live births [1,2], while the incidence of urinary tract malformations (UTM) was ascertained as 0.48% [3]. There are some preferential associations of UTM with intestinal defects, severe ear defects, central nervous system and heart defects [4]. Some authors reported that children with urinary tract anomalies have ten times greater incidence of CHD (8/100) compared to children in the general population (8/1000) [4]. In another series of 453 infants and children with UTM, 34 patients (8%) had CHD [5]. The symptoms of renal anomalies are usually silent, although there are some clues that may indicate the possible presence of these malformations such as the presence of single umbilical artery at birth, development of urinary tract infection (UTI), a history of oligohydramnios, external ear abnormalities [6] or suspected anomaly by antenatal ultrasound (US).

Association of CHD with extra cardiac malformations is ranging between 11–45% in autopsy findings and 11.4–29% in clinical studies [7]. The potential risk for acute renal injury and safety of cardiac surgery using cardiopulmonary bypass are particularly of great concern in the vulnerable small infants and neonates with renal anomalies requiring open-heart surgery [8].

Routine renal ultrasound screening prior to pediatric cardiac surgery is a routine practice in some tertiary centers but till now is not considered a recommended standard of care. In order to evaluate the prevalence of occult renal anomalies in association with CHD and to evaluate their effects on cardiac surgery, we conducted this prospective study to look for the presence of renal malformations and to assess the post-operative course of these children undergoing cardiac repair.

Material and methods

After obtaining informed consent and ethics committee approval from the Institutional Research Board of King Abdullah research center-King Abdulaziz Medical City IRBC/819/15; We conducted a cross sectional study for 100 consecutive children with no previous renal ultrasound who were admitted after cardiac surgery to PCICU from January 1st, 2015 till April 1st 2015.

The following data were collected for patients with renal anomalies in this study: Demographic information (age, weight, and gender), type of CHD, type of surgical procedures, bypass time, aortic cross-clamp duration, length of PCICU and hospital stay, evaluating specific outcome measures such as development of Acute Kidney injury (AKI) through monitoring peri-operative renal function (BUN, serum creatinine levels and urine output), the incidence of urosepsis and the need of peritoneal catheter or dialysis. Renal US was initially performed by trained PCICU intensivists and confirmed by radiologists. We followed an algorithm (Fig. 1) to confirm first the presence of both kidneys in normal position in renal fossae and then to assess the size and gross morphology of the kidneys. We used a General Electric (GE) ultrasound machine. Since most of the included populations were infants, we used transducer (8C) curvilinear probe with frequency 8–12 MHz. Depth was adjusted to get optimal image size (5–10 cm). While the patient was lying in supine position views were taken in sagittal plane with placing the probe in the lower intercostal space between anterior and posterior axillary lines; the marker was directed to 12 and 9 O'clock to get longitudinal and traverse views respectively (Fig. 2). Renal ultrasound training of intensivists and fellows was achieved by attending and performing a minimum of (10) cases of bedside focused renal ultrasound under supervision of expert radiologist and technician, in addition to review different archived cases stored in hospital library which
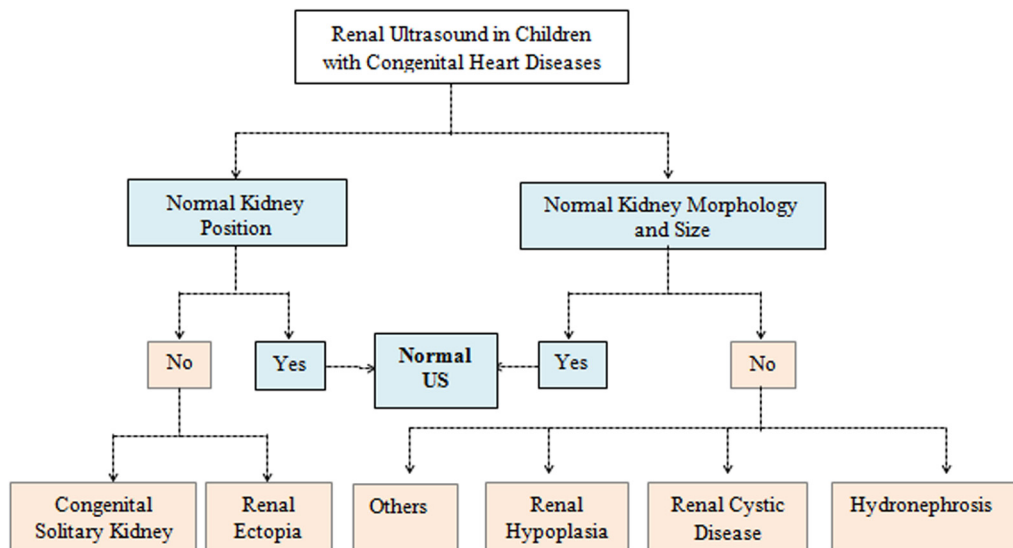
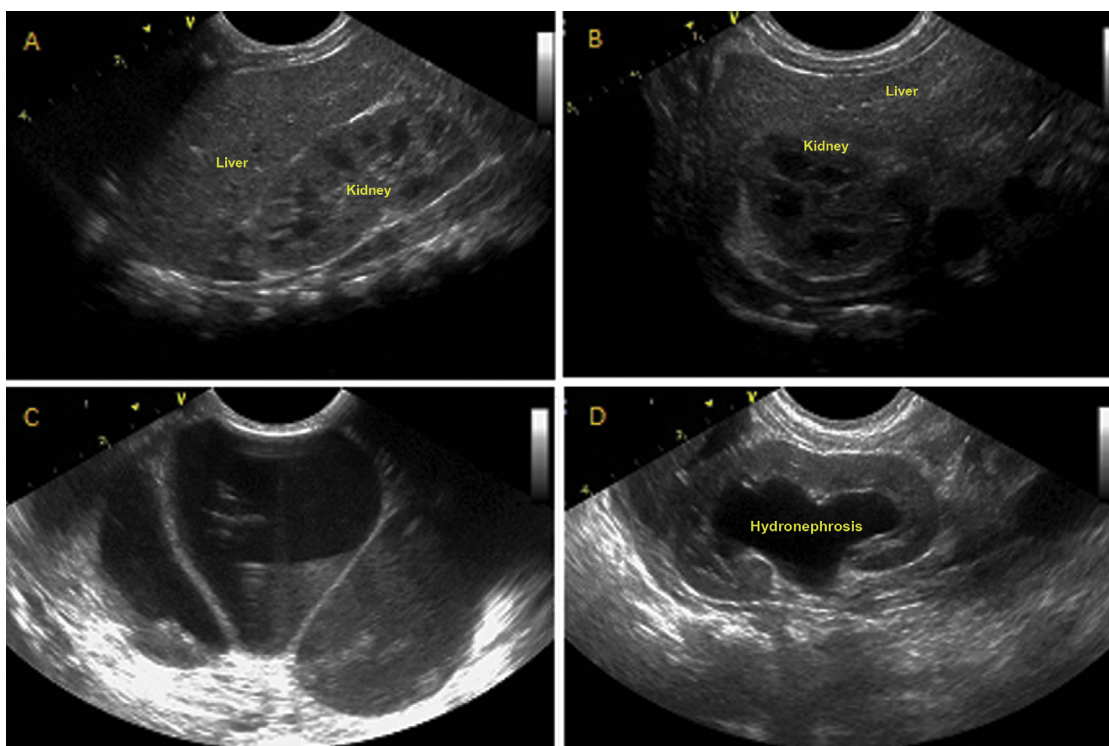Figure 1. Algorithm used in this study to guide the intensivist in renal US performance and its analysis.

Figure 2. Renal US views of our cases: A) Standard sonographer shape of the right kidney in long-axis view obtained through the liver demonstrating echogenicity of the normal renal parenchyma, which is approximately equal to the echogenicity of the normal liver. The renal sinus is hyper echoic compared to the renal parenchyma. B) Transverse (short axis) view of the normal right kidney. C) Multi-cystic dysplastic kidney: The left kidney is totally replaced by cysts. D) Significant hydronephrosis (marked dilation of the calices and renal pelvis).

explaining the algorithm cases, until achieving satisfactory competency in performing and analyzing bedside focused renal ultrasound in children. All frozen images and loops taken by intensivists in our study were analyzed and verified independently by expert radiologist in the

Table 1. Demographics of children with renal anomalies. AS: aortic stenosis; ASD, atrium septum defect; DORV, double outlet right ventricle; E, Female; M, male; m, months; N, number; PS, pulmonary stenosis; PA, pulmonary atresia; TAPVD, total anomalous of pulmonary veins drainage; TOF, tetralogy of Fallot.

No.	Diagnosis	Age (m)	Sex	Weight (kg)	Cardiac surgery	RACHS	Renal anomaly	Aortic cross clamping time	Cardio-pulmonary bypass time	Creatinine Pre-operative	Maximum creatinine post-operative	Foley catheter post-operative days	UTI episodes Peri-operative	PCICU/hospital Stay (days post-Surgery)
1	VSD	60	F	23	VSD	2	Right ectopic pelvic kidney	56	60	41	55	1	2	1/6
2	ASD, VSD	6	M	5.5	VSD	2	Right crossed-fused kidney	68	91	36	54	2	1	2/17
3	DORV, PS	7	M	5.6	TOF repair	2	Bilateral grade IV hydronephrosis	43	81	33	57	14	4	37/46
4	TAPVD	1	F	2.3	TAPVD	3	Left congenital solitary kidney	40	53	49	74	7	2	43/53
5	AS	24	M	10.5	Ross Cono	4	Left ectopic pelvic kidney	125	176	35	40	2	–	2/8
6	PA, VSD	0.5	M	2	TOF-like repair	2	Left multi-cystic dysplastic kidney	50	104	59	61	3	–	12/15

field through picture archiving and communication system (PACS).

Results

The average age and weight of the 100 children who were consecutively screened were 15 ± 9 months and 8 ± 3 kg, respectively. The Risk Adjusted Congenital Heart Surgery (RACHS) score in the 100 patients were: RACHS-1: 4%; RACHS-2: 55%; RACHS-3: 33%; RACHS-4: 6%; RACHS-5: 1%, RACHS-6: 1%. We visualized normal right and left kidneys with the standard sonographer shape in the renal fossae in 94 cases (94%). Prevalence rate of congenital renal anomalies in children with CHD was 6% (6/100 cases), with male predominance 66% (4/6 cases). The demographics of these 6 patients are displayed in Table 1. Mean cardiopulmonary bypass time and aortic cross-clamping time, were 93 ± 18 and 63 ± 13 minutes, respectively.

Further radiological investigation (such as Dimercaptosuccinic acid scan, a micturating cystourethrogram, intravenous pyelogram etc.) of these children with US-proven renal anomalies showed: 3 cases with ectopic kidney (50%), 2 cases with functional solitary kidney (33%) and one case with bilateral grade IV hydronephrosis (17%). Among the 3 patients with ectopic kidney, there was 1 case with right pelvic kidney, 1 case with left pelvic kidney and 1 case with right crossed-fused kidney. Among the 2 patients with congenital solitary functional kidney there was one case with left congenital solitary kidney and another case with normal left kidney in association with non-functional right multi-cystic dysplastic kidney. We did not find a specific association between the type of renal anomaly and specific cardiac disease. Urinary Tract Infection (UTI) occurred peri-operatively in 4/6 cases (66%) of patients with renal abnormalities with statistical significance (Odds ratio = 21.5 [3.39 to 136.12], 95% CI and $P = 0.0011$) compared to patients with normal renal US 8/94 (8.5%). Acute kidney injury post-surgery was not noticed in any patient with abnormal kidney US. The maximum increase in creatinine of these 6 cases was 15 ± 4 μmol/L postoperatively, which represents less than 50% increase from baseline pre-operative creatinine level. Their urine output remained adequate with an average of 3.8 ± 0.7 ml/kg/hour in the first 24-hour post-surgery. The creatinine levels trended to previous pre-operative values within 2.5 ± 0.5 days. We observed no significant renal insult and none of our cases with congenital renal

anomaly required any form of renal replacement therapy. Only one patient required peritoneal drain placement that was used for free passive drainage.

All patients with renal anomalies did well after surgery and had normal renal parameters that were similar to pre-operative renal values.

Discussion

Congenital anomalies occur in various combinations, the presence of one anomaly in one system will often indicate search for other anomalies [9]. The reported association between UTM and CHD may be due to common origin of embryonic tissues during development. Some transcription factors are highly expressed in the mesenchyme of developing organs including the kidney, lung, gut and heart and hence an insult to one of these organs during embryogenesis may cause defects in both the kidney and the heart [10].

In our study the prevalence rate of congenital renal anomalies in children with CHD was 6%. It was described to be up to 12% in another study, in which the authors reported 160 cases with kidney and UTM among 1340 patients with CHD [7]. In our study we focused only on isolated renal anomalies and did not look specifically for the anomalies of urinary collecting system and bladder. It is reported that isolated renal anomalies are associated with CHD more frequently than urinary collecting system anomalies [9]. However, we did not find a specific association between the type of renal anomaly and specific cardiac disease that is in line with previously published reports [7,9].

In our series, the incidence of ectopic kidney (pelvic) and crossed-fused renal ectopia in children with CHD were 2/100 and 1/100 respectively, while in literature the estimated incidence of each of these two anomalies is around 1:1000 [11,12]. On the other hand, we had also 2/100 cases with congenital solitary functional kidney. In both of these cases cardiac surgery on bypass was performed safely which is in agreement with previously published similar reports [8].

The incidence of Urinary Tract Infection (UTI) in febrile infants or symptomatic children is approximately 7% in several large studies [16–18]. In our 6 cases with abnormal renal US, UTI occurred in 66% peri-operatively with statistical significance in compared to 8% in patients with normal renal US undergoing cardiac repair. All patients undergoing pediatric cardiac surgery had a urinary catheter, which is a well-known risk factor in liter-

ature for urosepsis especially with long duration. In our study the duration of foley catheter insertion was not statistically significant in patients with urosepsis and abnormal renal ultrasound compared to whom with normal renal ultrasound (95% CI; −2.5 to 7.2, P 0.3). In our pediatric cardiac surgical cases, we use first generation cephalosporins (Cefazolin) for 48 hours as a standard postoperative prophylaxis mainly to minimize the risk of surgical site infection. However, this use is not targeted to prevent UTI. In our study UTI occurred in 4/6 patients with abnormal renal US, while long term antibiotic prophylaxis has been used in one case with bilateral hydronephrosis, the remaining patients with associated renal anomalies did not receive UTI long term prophylaxis as it has not been generally recommended. It is possible that increase risk of UTI might be related to other factors such as bypass time, cross clamp time and higher complexity of surgery. We observed parallel increase in the incidence of UTI with increasing cardiac surgical complexity reflected on RACHS score among the 94 patients with normal renal ultrasound. However, due to the small number of cases in abnormal renal ultrasound group (6 patients), this association was unclear and it could not be verified (Table 1). The presence of occult renal anomalies in our study was associated with higher UTI risk. Other risk factors might have also contributed to UTI. This should be evaluated in multicenters prospective study comparing children with UTM and CHD and those with CHD and normal renal US.

The reported incidence of acute kidney injury after pediatric open-heart surgery varies from 1.6% to 52% [13]. In the study conducted by Liu and colleagues they defined acute kidney injury as 50% or greater increase in serum creatinine from baseline within 3 days after surgery [14]. Detailed review of our 6 cases showed that 3 cases (50%) had transitional acute kidney injury before surgery that was corrected prior to surgery. Normalizing renal parameters and supporting hemodynamics preoperatively may have a potential positive effect on morbidity and outcome in our cases. It was mentioned in several studies that elevated preoperative serum creatinine is perhaps the strongest predictor for developing acute kidney injury after cardiopulmonary bypass (CPB) [15].

Acute kidney injury is reported to be associated with longer CPB times. Other factors such as flow rates and perfusion pressures are very important determinants of adequate nutrient delivery kidney vascular bed [13,15]. In our 6 cases with

abnormal kidney US, mean cardiopulmonary bypass time and aortic cross-clamping time, were 93 ± 18 and 63 ± 13 minutes, respectively without major negative effects on kidney function. We observed no correlation between prolonged CPB times and maximum increase in creatinine.

In general we observed no discrepancy between intensivist and radiologist in classifying the ultrasound as normal versus abnormal and in detecting the major anomalies prescribed in the algorithm (Fig. 1). We believe that screening performed by intensivist at bedside is simple, non-invasive easy and practical test that can be taught to all trainees in ICU field and can be performed with no or minimally added cost to the patients. It requires no mobilization of patients and has no radiation exposure. The use of US as a screening tool in ICU is becoming widely accepted practice and helped in answering many questions that supported the diagnosis and management of critically ill patients.

Limitations

Our study has some limitations to generalize the results; including the fact that it is a single center experience done on a small sample size of children underwent cardiac surgery, and we recommend doing multicenter study to expand the population. On the other hand, the interpretation of ultrasound findings in general is heavily dependent on operator experience represents one important limitation. Our 6 patients with abnormal ultrasonographic renal findings were non syndromic by clinical appearance, but the genetic studies were not routinely investigated adequately to be correlated with coexisting renal anomalies. However we believe in fact that learning basics of renal ultrasound will add additional skills to pediatric intensivist that will help in diagnosing occult kidney abnormalities and make the health care provider more vigilant about the increased risk of urosepsis during peri-operative care.

Conclusions

Routine renal US in children with CHD demonstrated prevalence of associated congenital renal anomalies in 6% of children undergoing cardiac surgery. The presence of occult renal anomalies was associated with higher UTI risk. Performing renal US as a standard practice in all children with CHD is justifiable, and early screening by urine analysis and culture to rule out UTI for any sign of nosocomial infection is recommended in children with renal anomalies.

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