



Contribution of Serial Focused High-Resolution Renal Ultrasound in the Management of a Neonate in Acute Renal Failure

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Abstract

Most newborns begin urinating within 24 hours of life, and almost always by 48 hours. Rarely, some of them are anuric beyond 24 hours, thereby causing concern to parents and treating doctors. We report the case of a newborn who presented with anuria till 48 hours after birth. High-resolution ultrasound examination, focusing on the renal medulla, demonstrated increased echogenicity at the tip of the pyramids. This was attributed to slow clearance of urinary sediment deposited there, which was causing obstruction to the urinary outflow. On monitoring serially over the next few days, the echogenic sludge was observed being slowly eliminated leading thereby to improvement in the urinary output. High-resolution ultrasound focusing on the renal pyramids played an important role in the observation and management of this transient event unfolding, in the urinary tract.

Keywords

- ▶ pyramids
- ▶ echogenicity
- ▶ anuria
- ▶ renal medulla
- ▶ echogenic sludge

Key Message

The sonographic findings of increased medullary echogenicity caused by deposits of urinary sediments, at the tip of the medullary pyramids and observing their gradual clearance with improving urinary output, highlights the value of focused high-resolution ultrasound in the management of this transient situation, causing reversible acute renal failure in the newborn.

Introduction

Almost 95% newborns start urinating within 24 hours of life, and nearly always by 48 hours. When urination is delayed, or is scanty, it leads to concern for any urinary abnormality and further investigations including ultrasound is advised for appropriate management. The renal medulla and pyramids

in neonates normally appear hypoechoic, relative to the cortex. Various pathophysiologic processes in newborns and children can cause increased echogenicity of the renal medulla and its pyramids.¹ It has become possible to visualize these appearances using focused ultrasound with high-frequency transducers.² We present the report of a newborn who was anuric till 48 hours of life and while on treatment in the hospital, was monitored serially by using focused high-frequency ultrasound, till complete resolution of the anuria.

Case History

A 48-hour-old male neonate was brought to the pediatric outpatient department with complaints of not having passed urine since birth. The baby had a domiciliary delivery by a trained birth attendant. He cried immediately after birth,

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was on exclusive breastfeeding but the mother noticed that he was sleeping quietly most of the day, was not suckling too well, and hardly demanding any feeds.

On admission (day 1), the baby appeared dehydrated with a temperature of 37.1°C, pulse rate 142 beats per minute, respiratory rate 45 breaths per minute, and the oxygen saturation 98% on room air. The blood pressure was 62/33 mm Hg. Systemic examination did not reveal any physical abnormality. No abdominal or pelvic mass was felt. His nappy pad was dry.

The laboratory parameters showed a blood urea level of 29 mg/dL, serum creatinine 3.3 mg/dL, serum sodium 156 mEq/L, serum potassium 4.8 mEq/L, and C-reactive protein 0.28 mg/dL. The blood gases were within normal limits. Complete blood counts were also in the normal range for newborns.

An urgent bedside ultrasound was performed by the resident on call, using a Philips CX 50 portable unit having a convex C5-1 and linear L12-3 probe. It did not reveal any evidence of urinary tract obstruction or any other gross pathology.

After two fluid boluses (40 mL per kg), administered on admission, the baby was started on maintenance fluids (100 mL per kg) without supplemental potassium. Since the urine output remained low, the maintenance fluids administration was guided by insensible water loss for a full-term neonate.³ (Insensible water loss is loss of water through skin, mucous membranes, and respiratory tract.)³ Antibiotics were empirically started. Serial renal function tests, serum electrolytes, and urine output are shown in **Table 1**.

The following day (day 2) as well as on subsequent days (till day 5), follow-up ultrasonographic evaluation was performed in the main imaging department using one of the readily available high-end machines (Samsung RS 80A, Philips Lu 22, or GE Voluson 8). The examination was performed with a convex pediatric probe followed by high-frequency linear array probe (11–16 MHz), focusing on the renal parenchyma, especially the renal pyramids.

During the procedure the neonate was kept warm and jelly, heated to room temperature, applied before scanning. The examination was performed in the supine, decubitus, and prone positions, the latter allowing adequate visualization of the kidneys without the obstructive effect of bowel gas shadows. Since the footprint of some of the linear probes was relatively large, both kidneys could be examined simul-



Fig. 1 Day 2. Focused scan of the kidney, using a high-frequency linear probe with a trapezoidal field of view, shows increased medullary echogenicity concentrated at the tip of the renal medulla (arrows).

taneously in the transverse plane. This aided in side-by-side comparison of the kidneys in a single image.

The images were magnified and the focal zone suitably adjusted. Normally, the renal medulla, composed of several pyramids, appears hypoechoic in a newborn. In this case, the medulla showed increased echogenicity concentrated more at the tip of the pyramids, as compared with the base (**Fig. 1**). The bladder was almost empty at the time of this scan (day 2).

This finding of selective concentration of echogenicity at the tip of the renal pyramids, with relatively clear hypoechoic bases, unlike in a case of medullary nephrocalcinosis, enabled us to suggest the possibility of transient renal medullary echogenicity as a cause of acute renal failure. The neonatologist, taking cognizance of the ultrasound report, continued with the standard treatment protocol of dehydration, which was based on laboratory parameters and clinical status of the patient.

On day 3, the echogenic sludge was found gravitating slowly into the calyces and pelvis (**Fig. 2**). A small quantity of urine with echogenic debris appeared in the urinary bladder. The baby had also started passing small quantities of urine in the nappy. Scan done on day 4, showed the calyces were nearly clear with the echogenic debris now mainly in the renal pelvis (**Fig. 3**). On day 5 (**Fig. 4**), most of the

Table 1 Serial laboratory parameters, urine output, and weight of the neonate

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Urea (mg/dL)	29	39	45	44	38	23	11	6
Creatinine (mg/dL)	3.3	3.25	2.82	2.27	1.93	1.11	0.7	0.49
Sodium (mEq/L)	156	141	144	143	141	142	138	140
Potassium (mEq/L)	4.8	5.25	5.05	6.5	5.9	4.9	5.0	5.2
Urine output (mL)	10	24	10	30	35	75	135	100
Weight (kg)	2.44	2.52	2.6	2.8	2.88	2.95	2.88	2.86

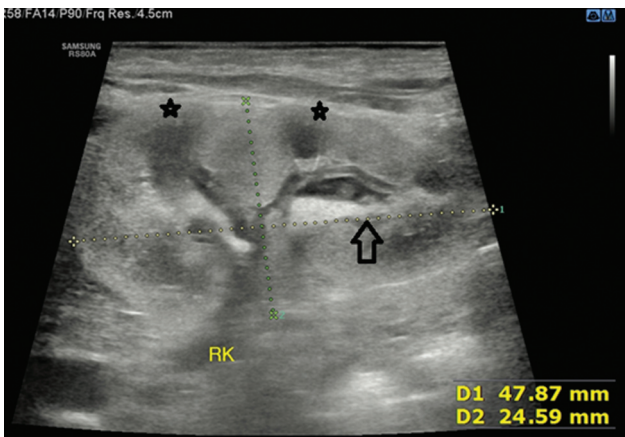


Fig. 2 Day 3. The echogenic deposits are seen in the calyces (arrow). Note the clearing of the medulla (black star).



Fig. 3 Day 4. The deposits have shifted from the calyces into the renal pelvis (arrows).

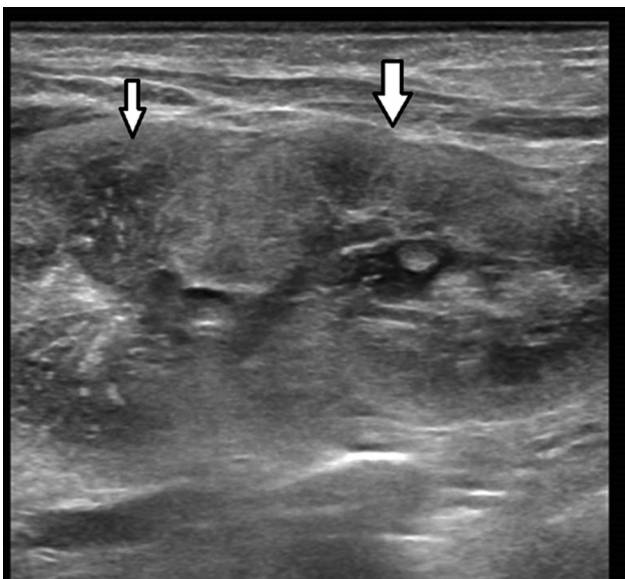


Fig. 4 Day 5. The renal medulla now shows a normal hypoechoic appearance with a few residual echogenic crystals still visible within them (arrows).

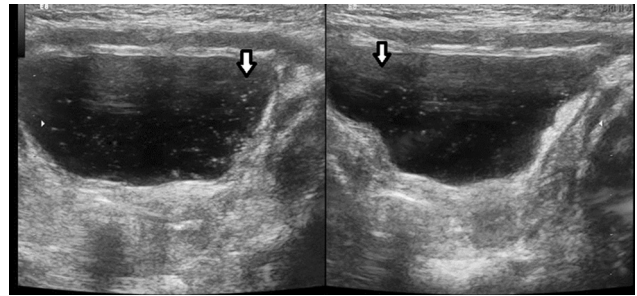


Fig. 5 Day 5. The bladder shows improved filling with echogenic crystals floating within it (arrows).

pyramids showed normal hypoechoic appearance, barring a few residual echogenic foci within some of them. The pelvis had also cleared significantly. The urine in the partially filled bladder was now larger in quantity and clearer with a few echogenic mobile foci still visible within it (►Fig. 5). The baby was discharged on 8th day in a good condition. He was followed up in the outpatient department and being in good health, was not subjected to any further investigations.

Discussion

Ultrasound plays an important role in the evaluation of the urinary tract. The presence or absence of kidneys, their sizes, uni- or bilateral hydronephrosis, dysplastic lesions, focal or generalized medullary hyperechogenicity, and evidence of bladder outlet obstruction, aid in diagnosing the many conditions, including those causing anuria.¹

With the availability of advanced ultrasound machines, the sonographic appearance of neonatal kidneys can be studied in great detail, especially by using a high-frequency probe (11–16 MHz) and applying a focused approach. By focused ultrasound approach, is meant that a small area of the kidney is magnified and studied in detail with the highest frequency transducer available. Unlike a routine ultrasound scanning, as was performed at bedside, ultrasound with high-resolution probes, enables macroscopic evaluation of the structure of the renal parenchyma.² A high-frequency convex or better still, a linear array probe focusing on the area of interest,² yields exceptional images.

The kidneys can be evaluated in decubitus or prone positions. The prone position often works well, as some babies are more comfortable in this position and both kidneys can be compared side by side.

Neonatal kidneys have an appearance different from adult kidneys.⁴ The cortex in neonates is as echogenic as the liver, even more so in preterm babies.⁵ The reason is compaction of glomeruli and loops of Henle within a smaller area. This leads to more interfaces and increased echogenicity.⁶ It usually takes 4 to 6 months for the cortical echogenicity to reduce to a normal lower level when compared with the liver.

The renal medulla of neonates is larger as compared with the older age group and hypoechoic (►Fig. 6). The renal sinuses are devoid of fat in early neonatal period and do not appear echogenic. The tip of a pyramid of the renal medulla is enclosed by a calyceal cup, the walls (fornices) of which

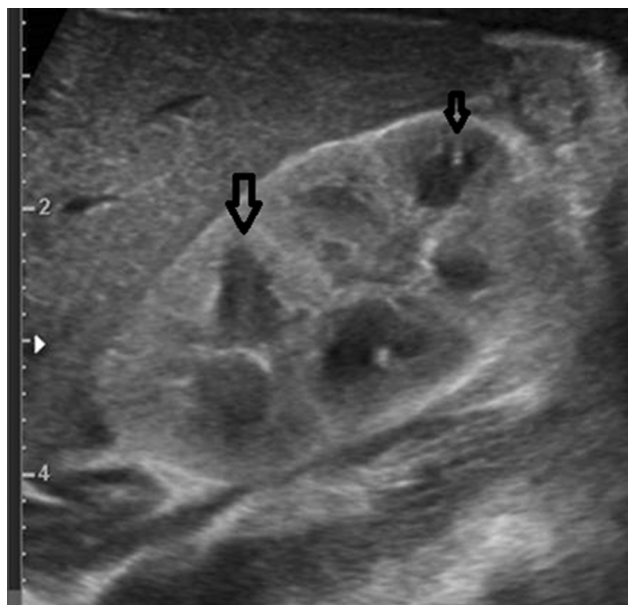


Fig. 6 Normal kidney of a neonate showing echogenic cortex and hypoechoic medulla (arrows).

appear echogenic when opposed to each other. They appear isoechoic, when spread apart by urine. Neonates with a normal ultrasound appearance as described have a normal urine output within the first 24 hours.¹

The increased echogenicity, as was seen in the reported case, appeared to be due to deposition of endogenously produced substances at the tip of the renal papilla and was slow to clear, hence causing transient outflow obstruction. As the glomerular filtration rate began improving, the echogenic sludge cleared from the base of renal pyramid, shifting toward the tip. The base of the pyramids therefore showed a normal hypoechoic appearance. This process of clearance took several days.⁷ The echogenic debris gradually emptied into the calyces, then gravitated into the pelvis and flowed out into the bladder, being ultimately washed off by urination. The entire process of clearance of the echogenic debris from the urinary tract, could be witnessed during real-time scanning. It coincided with improvement in renal status of the patient.

Neonatal renal failure is a serious condition and has been attributed to severe perinatal asphyxia, sepsis, disorders of the urinary tract, and various nephrotoxic drugs.⁸ The outcome is often poor and may lead to death or long-term complications in survivors. However, a condition called “neonatal transient renal failure associated with medullary hyperechogenicity” has been described in literature and has a favorable outcome.⁷ Makhoul et al described a case series of 9 neonates of this benign entity with excellent outcome.⁷

Transient medullary hyperechogenicity is seen in 3.9 to 58% neonates.⁹ While the clearance of the echogenic debris, observed in real-time ultrasound, with rapid improvement in the clinicopathological status in a matter of few days, precludes any obstructive pathology, the etiology of transient renal medullary echogenicity, is still unclear.¹⁰



Fig. 7 A case of nephrocalcinosis, showing diffusely echogenic renal medulla (arrows).

It is probably a physiologic event but several alternatives have been suggested.⁹ Based on the reviewed literature and our own experience, we compiled **Table 2**, which is a summary of the likely etiologies of increased renal medullary echogenicity.^{11,12}

The main considerations were urinary tract obstruction and renal medullary nephrocalcinosis²:

1. In urinary tract obstruction, increased medullary echogenicity may be observed as a curvilinear rim encircling the dilated calyces. This could be due to the stacking up of obstructed dilated pericalyceal tubules, creating many reflective interfaces as in multiple small renal cysts, thereby resulting in increased medullary echogenicity.¹³
2. In renal medullary nephrocalcinosis, there is either diffuse (**Fig. 7**) or peripheral increase in renal medullary echogenicity with central sparing (**Fig. 8**), unlike in this reported case which showed increased echogenicity predominantly localized at the tips of the renal pyramids with relatively clear bases that were abutting the renal cortex. It is a disease which lasts longer and may be

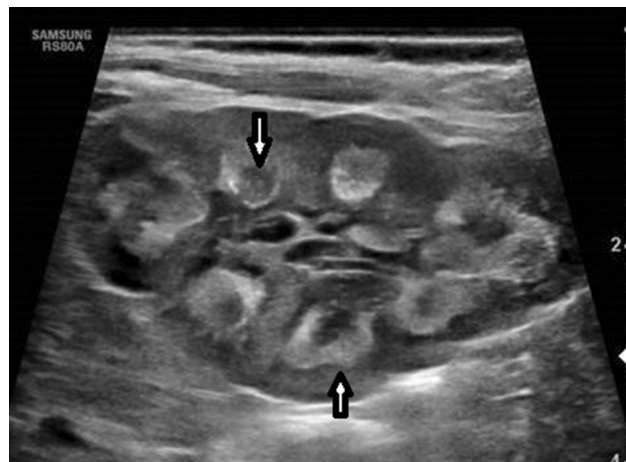


Fig. 8 Another case of nephrocalcinosis, showing echogenicity in periphery of the renal medulla with central sparing (arrows).

Table 2 Differential diagnosis of increased neonatal renal medullary echogenicity

Conditions	Clinical factors	Ultrasound features
Autosomal recessive polycystic kidney disease (ARPKD) (ADPKD may also mimic ARPKD in some cases)	May be detected in prenatal ultrasound. May be syndromic (Beckwith–Wiedemann syndrome)	Enlarged kidneys with diffusely hyperechoic pyramids with dilated ducts forming cystic space. Presence of numerous discrete echogenic foci casting a comet tail shadow
Lesch-Nyhan syndrome	Increased urate crystal deposits The drug allopurinol used for treatment may also, as a side effect, be a causative factor, by depositing xanthine crystals in the pyramids	Diffuse echogenicity of the pyramids with central sparing
Glycogen storage disease	Type 1 is commonly associated with renal involvement	Nephromegaly with increased corticomedullary echogenicity secondary to glycogen, urate, and calcium deposition
Sickle cell anemia	Older children in the first decade, usually affected. Unlikely in newborns	Increased echogenicity of the entire kidney/throughout medulla/central medulla or tips of pyramid ¹⁴
Obstructive uropathy	Longer course of illness. May accompany pain, UTI, hematuria	Features of obstructive uropathy with curvilinear medullary echogenicity around the dilated calyces
Acute renal failure	H/o sepsis, prematurity, birth anoxia, drug intake, etc.	Findings may mimic the ultrasound findings or transient increase in echogenicity
Hyponatremic state	Low serum sodium levels	May show identical US findings
Renal medullary nephrocalcinosis of the neonate	Longer course of the disease Patients may be normocalcemic or hypercalcemic	Diffuse/peripheral increase in echogenicity of the renal medulla without / with slight shadowing. The central area and extreme periphery of the medulla may be spared even in the peripheral type of increased echogenicity. Echogenicity may involve the cortex also. Ultrasonographic and clinic state lasts longer
Ischemia	H/o perinatal asphyxia	Mild diffuse heterogeneously increased echogenicity. Exclude renal vein thrombosis
Candida infection	Urinary tract infection, catheterization, immunodeficiency, congenital urinary tract abnormalities	Hyperechoic pyramid, resembling transient increased echogenicity of the renal pyramids. Echogenic non shadowing ball-like sloughed off papilla/mycetoma in the renal outflow tract
Transient increased echogenicity of uncertain etiology ¹⁵	May not be associated with any biochemical abnormality	Diffusely echogenic renal medulla ¹¹
Transient increased echogenicity related to maturation of tubules	Diminished urinary output	Hyperechoic tips of renal papilla only. ¹⁴ May be the same or a similar entity

Abbreviations: H/o, history of; US, ultrasound; UTI, urinary tract infection.

Note: Summary of the postulated etiologies of increased renal medullary echogenicity in children (11, 13, and Authors' experience).

- associated with hypercalcemia. The ultrasound findings are, therefore, different in this disorder.
- The neonate had hypernatremia, hence hyponatremic dehydration causing increased medullary echogenicity could be discounted.
 - The possibility of deposition of endogenous substances (likely uric acid) has been postulated to be one of the causes, leading to tubular stasis and transient acute renal failure.⁶ Hyperuricemia has been documented in many of these neonates.⁶ Uric acid crystalluria has been observed in up to 70% of these neonates. The possibility of urate crystals deposited in the papilla could not be excluded since we could not obtain urine samples.
 - Deposition of Tamm–Horsfall protein produced by tubular cells has also been postulated by some authors, but could not be substantiated in this patient.
 - Perinatal asphyxia resulting in renal hypoperfusion may also be a factor by causing hyperuricemia and tubular cell damage. As the newborn was delivered at home, perinatal asphyxia might have contributed to the renal failure. Inappropriate initiation of feeding may also have aggravated the renal failure in the patient.

In conclusion, we present this case report because it highlights the utility of focused high-resolution ultrasound in the diagnosis and management of patients of transient acute renal

failure in neonates. The ultrasonographic findings of increased renal medullary hyperechogenicity, due to stasis of echogenic sludge at the tip of the renal papilla, followed by gradual clearance with correction of dehydration and improvement in the urinary output, were highly suggestive of this unusual entity causing transient renal failure in the newborn. That the appearance of the kidneys normalized in a few days, underlines the importance of recognizing this condition causing transient stasis nephropathy.¹³ The ultrasonologist is in a good position to recognize this condition thereby contributing substantially in the management of these patients.

Learning Points

1. Ultrasound, especially focused high-resolution ultrasound, is an invaluable tool in the investigation of renal anomalies, in neonates and infants.
2. The sonographic features of transient oliguria/anuria due to a benign self-limiting cause can be different from other more serious conditions such as renal medullary nephrocalcinosis.
3. Presence of echogenic sludge mainly concentrated at the tip of the renal pyramids with gradual clearance, as the glomerular filtration rate improves, enables suggesting this transient cause of acute renal failure in the neonate.
4. Follow-up ultrasound may be required only if clinical or laboratory findings raise a red flag.

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Conflict of Interest
None.

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