Saudi Journal of Medicine and Public Health

https://saudijmph.com/index.php/pub

https://doi.org/10.64483/202631678

Optimizing Ultrasound Gain Settings for Enhanced Detection of Bladder Debris in Pediatric Cystitis at KSMC, Riyadh

Faizah Alanazi (1) , Adbdulelah Awadh Almutairi (1) , Dr. Mohammed Moauad (1) , Shadi Ghali Alharbi (1) , Dr. Kamal Alshamiri (1)

(1) King Saud Medical City,Ministry of Health, Saudi Arabia

Abstract

Background and Introduction: Cystitis is a common pediatric condition often caused by bacterial infection. Early diagnosis is essential to prevent long-term complications such as renal scarring and recurrent infections. A key ultrasound finding in cystitis is the presence of bladder debris, which indicates inflammation or infection. Despite the widespread use of ultrasound for pediatric urinary tract evaluation, variability in gain settings significantly affects the visibility of bladder debris. Currently, there is no standardized guideline on optimal gain settings for this purpose. King Saud Medical City (KSMC), Riyadh, aims to address this diagnostic gap through targeted optimization of ultrasound imaging protocols.

Aim: To optimize ultrasound, gain settings to improve the detection and diagnostic accuracy of bladder debris in pediatric cystitis cases at KSMC.

Methods: This retrospective observational study will include 70 pediatric patients (aged 2 months to 12 years) underwent bladder ultrasound as part of routine evaluation. Each patient had five transverse bladder images captured using incremental gain settings (40%, 50%, 60%, 70%, 80%) on GE LOGIQ E9 and LOGIQ ultrasound machines. A curvilinear probe (2–9 MHz or 1–6 MHz) used based on patient age. Two radiologists independently assessed the clarity and presence of bladder debris using a standardized scoring system then by two technologists. Findings will be compared to clinical data, including urinalysis (leukocyte esterase, nitrites, pyuria) and urine culture, to evaluate diagnostic sensitivity and specificity at each gain level.

Results: This study anticipates that moderate ultrasound gain settings, specifically between 60% and 70%, will significantly improve the clarity and visibility of bladder debris, thereby enhancing diagnostic accuracy compared to lower or higher settings. This optimized range is expected to show a stronger correlation with clinical findings and decrease the likelihood of under-detection or misdiagnosis.

Conclusion: The optimization of ultrasound gain settings holds the potential to elevate the diagnostic accuracy for pediatric cystitis by improving the visualization of bladder debris. The study's outcomes are intended to support the development of standardized gain protocols, contributing to evidence-based advancements in pediatric imaging practices at our institution and potentially influencing practices elsewhere. This way of working may also decrease unnecessary procedures and enhance overall patient care.

Keywords: Ultrasound gain, Pediatric cystitis, Bladder debris, Urinary tract infection, Diagnostic imaging, Urine culture, Sonography optimization.

Introduction

Cystitis is defined as an inflammatory disorder of the urinary bladder and is most commonly encountered as a manifestation of bacterial urinary tract infection [1]. It continues to represent a substantial global public health burden, with epidemiological analyses from the period 2020–2025 confirming sustained high incidence rates worldwide. In 2019 alone, approximately 404.61 million new cases were reported, reflecting an increase of more than 60% compared with figures recorded in 1990. This rising burden is disproportionately observed among females, a pattern that is consistently attributed to anatomical and physiological factors such as shorter urethral length and the close proximity of the urethral opening to perineal and gastrointestinal bacterial reservoirs. These factors facilitate ascending bacterial colonization and partially explain the marked sex-related disparity in disease prevalence. Uropathogenic *Escherichia coli* remains the dominant causative organism, responsible for an estimated 75–95% of uncomplicated cystitis cases [1–2]. Other clinically relevant uropathogens include *Klebsiella pneumoniae*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, and species of *Enterobacter*, in addition to gram-positive organisms such as *Staphylococcus saprophyticus* and *Enterococcus faecalis* [3–4]. The pathogenesis of cystitis is complex and multifactorial, involving ascending infection from periurethral colonization by enteric flora, followed by firm bacterial adherence to the bladder urothelium. This

*Corresponding author e-mail: faizaa.m.f@gmail.com (Faizah Alanazi).

Receive Date: 01 February 2026, Revise Date: 02 February 2026, Accept Date: 03 February 2026

adhesion is mediated by specific virulence determinants, including fimbrial adhesins such as FimH, PapG, and CsgA, alongside flagellar motility, hemolysin production, and siderophore-mediated iron acquisition. Contemporary molecular and cellular studies have further demonstrated that uropathogens can invade urothelial cells and establish intracellular bacterial communities, thereby evading host immune responses and contributing to persistence and recurrence of infection [3–5].

Clinically, cystitis typically presents with dysuria, increased urinary frequency, urgency, suprapubic discomfort, and, in some cases, hematuria. Diagnostic evaluation has traditionally relied on urinalysis findings, particularly pyuria defined as five or more leukocytes per high-power field, in conjunction with bacteriuria. Urine culture remains the reference standard for microbiological confirmation, commonly using a threshold of at least 100,000 colony-forming units per milliliter, although lower counts may be diagnostically meaningful in symptomatic individuals. In recent years, diagnostic stewardship has increasingly emphasized symptom-based assessment, reserving routine urine cultures for complicated cases, recurrent infections, or treatment failure in order to reduce unnecessary testing and antimicrobial exposure [6–7]. Ultrasonography has emerged as a cornerstone noninvasive imaging modality in the assessment of cystitis, particularly in pediatric populations. One of the most frequently described sonographic findings is the presence of intravesical echogenic material, commonly referred to as bladder debris, which is considered a hallmark of inflammatory or infectious bladder pathology. Despite its clinical relevance, detection of bladder debris remains technically challenging. These challenges are amplified in children due to smaller bladder size, variable distention, limited patient cooperation, and inherent constraints of conventional ultrasound systems. Advances between 2020 and 2025 have highlighted multiple optimization strategies, encompassing technical parameter refinement, structured scanning protocols, and the application of novel imaging technologies, all aimed at improving diagnostic reliability in cystitis evaluation [11].

Bladder debris appears sonographically as mobile, hyperechoic particulate matter within the bladder lumen and reflects the presence of desquamated urothelial cells, inflammatory cell aggregates, proteinaceous material, or purulent sediment associated with acute infection. A landmark study by McQuaid and colleagues demonstrated a strong association between sonographically detected bladder debris and positive urine cultures in pediatric patients evaluated following urinary tract infection. In this cohort of children younger than 60 months, the presence of debris was associated with a nearly eightfold increase in the likelihood of a positive catheterized urine culture, corresponding to a 688% increased probability of active infection [11–12]. Subsequent studies have reinforced these observations and further linked bladder debris to elevated inflammatory markers, microscopic hematuria, and additional sonographic abnormalities such as renal pelvic debris and collecting system wall thickening, although associations with specific uropathogens have shown variable consistency across studies [13]. Pediatric bladder ultrasonography is subject to numerous technical limitations. These include anatomical constraints related to small bladder capacity, physiological variations in bladder filling, motion artifacts arising from respiration or movement, and operator dependence in image acquisition and interpretation. Artifacts inherent to ultrasonography, such as side lobes, beam width effects, and reverberation, may either mimic intraluminal debris or obscure true pathology. Measurement of bladder wall thickness is similarly sensitive to bladder distention, with established pediatric norms demonstrating thinner walls in distended states and thicker measurements in collapsed bladders. Values exceeding three millimeters in adequately distended bladders are generally considered suggestive of pathological thickening related to inflammation or chronic detrusor changes [14–15].

Optimization of ultrasonographic assessment relies heavily on appropriate technical settings and standardized protocols. Transducer selection, gain adjustment, bladder distention, and multiplanar scanning all play critical roles in maximizing debris detection. Emerging technologies such as contrast-enhanced ultrasonography, elastography, and wearable ultrasound devices offer promising avenues for improved tissue characterization, functional assessment, and continuous bladder monitoring, although many applications remain investigational in pediatric cystitis [18–20]. Accurate artifact recognition and mitigation remain essential competencies, as misinterpretation can lead to diagnostic error and inappropriate management [21]. Integration of sonographic findings with clinical symptoms, laboratory results, and inflammatory biomarkers is essential for accurate diagnosis. While bladder debris is strongly associated with infection in symptomatic patients, its isolated presence in asymptomatic children requires careful contextual interpretation. Dynamic assessment of bladder wall thickness before and after voiding, as well as evaluation of bladder emptying efficiency, provides additional functional insights relevant to recurrent infection risk and disease chronicity [22]. Future research priorities include standardization of debris quantification, development of artificial intelligence-assisted detection algorithms, and longitudinal studies correlating sonographic findings with long-term clinical outcomes [23].

The primary aim of this research is to optimize ultrasound gain settings to improve the detection and diagnostic accuracy of bladder debris in pediatric cystitis cases at King Saud Medical City in Riyadh. To achieve this aim, the study evaluates the effects of varying gain levels ranging from 40% to 80% on debris detection, examines how gain adjustments influence image clarity and debris conspicuity, and compares ultrasound findings obtained at different gain settings with clinical outcomes, including urinalysis and microbiological culture results [24–25]. Through this comparative analysis, the study seeks to identify an optimal gain range that supports standardized imaging protocols, enhances imaging quality, and reduces diagnostic errors in routine clinical practice. By addressing gain optimization within a high-volume tertiary care setting, the study aims to contribute meaningful evidence toward improving pediatric ultrasound practice and diagnostic pathways for urinary tract infections [26].

Methodology:

The present investigation adopts a retrospective observational design focusing on pediatric patients who underwent routine kidney, ureter, and bladder ultrasonography. The central variable under evaluation is the ultrasound gain setting, systematically examined across five predefined levels ranging from 40% to 80%. Imaging was performed using GE LOGIQ E9 and LOGIQ ultrasound systems equipped with curvilinear transducers, with probe frequency selection tailored to patient age and body habitus, utilizing ranges of 2–9 MHz or 1–6 MHz as clinically appropriate. All examinations were conducted according to standard pediatric abdominal ultrasound protocols, with gain adjustments applied sequentially during the same imaging session to ensure internal consistency and comparability. The study population comprised pediatric patients between two months and twelve years of age who were clinically suspected of acute cystitis or underwent abdominal or renal ultrasound for unrelated indications in which bladder debris was incidentally identified. Patients younger than two months or older than twelve years were excluded to maintain population homogeneity and to account for developmental differences in bladder anatomy and physiology. Additional exclusion criteria included known chronic systemic or hematological conditions such as diabetes mellitus, sickle cell disease, or other disorders that could confound urinary findings or alter bladder wall characteristics. Eligible patients were identified from pediatric outpatient clinics, inpatient wards, and emergency departments, reflecting a broad clinical spectrum and enhancing the generalizability of findings.

A total of seventy pediatric cases meeting the inclusion criteria were included during the study period extending from July to December 2025. Sample size determination was based on a 95% confidence level, a 5% margin of error, and an estimated bladder debris detection prevalence of 50%, yielding a minimum required sample of sixty-seven participants. Enrollment of seventy cases allowed for sufficient statistical power while accounting for incomplete data or potential exclusions during analysis. All ultrasound examinations were performed with the patient in the supine position, and transverse imaging planes were used to standardize bladder visualization across all gain levels. Given the noninvasive nature of ultrasonography, the procedure posed minimal risk to participants and required no additional safety precautions beyond routine clinical practice. Standard ultrasound gel and integrated gel warming systems were employed to optimize patient comfort and image quality. Imaging data were retrieved retrospectively from the institutional electronic archiving system, and all collected data were stored securely in password-protected files accessible only to the research team. The study was conducted in accordance with the Declaration of Helsinki and complied with institutional bioethical regulations, ensuring confidentiality and data protection throughout the research process.

Ultrasound images acquired at each gain level were independently reviewed by two experienced radiologists, followed by assessment by two qualified sonographers, all of whom were blinded to clinical and laboratory findings. Bladder debris was evaluated in terms of clarity and visibility using a predefined scoring framework to ensure consistency across observers. Inter-rater reliability was assessed using Cohen’s kappa coefficient to quantify agreement among evaluators. Clinical correlation was established using urinalysis and urine culture results, which served as the reference standard for confirming cystitis. Statistical analysis was performed using IBM SPSS Statistics version 26. Descriptive statistics summarized demographic characteristics and imaging findings. Diagnostic performance measures including sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each gain setting. Inferential analyses were conducted to examine differences in debris detection and image clarity across gain levels, employing chi-square tests for categorical variables and parametric or nonparametric tests for continuous variables based on data distribution. Comparative analyses across the five gain settings utilized analysis of variance or Kruskal–Wallis testing with appropriate post hoc comparisons. Statistical significance was defined at a threshold of p less than 0.05.

Results and Discussion:

Technical Data:

In this study, we looked at 70 children—from a newborn of just two months up to a 12-year-old—who needed an ultrasound of their bladder because of suspected cystitis. Each child's bladder was scanned three times, using the same convex probe (2–9 MHz), but with three different gain settings on the machine: low (40), normal (50) and high (80). The goal was to find out which gain level gives the clearest picture of any debris floating in the bladder. For each scan we judged how well the debris could be seen, how sharp the overall image was for, and whether the findings were consistent across the three settings. By keeping the scanning technique, the same for every child, we tried to limit differences that might come from the operator rather than the equipment. After the scans, we will run statistical analyses in SPSS to see if changing the gain really changes the contrast and reliability of the debris detection. The ultimate aim is to create evidence-based guidelines that tell clinicians the best gain setting to use when performing bladder ultrasounds in children (**Table-1**).

Table-1: Technical Data of US Analysis in the present study.

Item	Data
Analysis Type	US analysis
Device Model	US (LOGIQ E9 and LOGIQ) models
Probe Type	C (2-9) and C (1-6)
Perset Gain	50
High Gain	80
Low Gain	40
Target Disease	Cystitis
Target Detection	Clear picture of debris
Target population	Pediatrics
Target age	Aged between 2 months – 12 years
No. of Cases	70

Descriptive Analysis:

The investigation examined 70 pediatric ultrasound examinations to identify the gain setting that yields the most reliable detection of bladder debris. Image quality and debris visibility varied markedly with gain. The optimal setting was a gain of 70, which provided the clearest debris visualization in 55.7 % of cases. A gain of 60 was optimal in 35.7 % of examinations, while only 1.4 % each favored gain of 40 and 50, and 5.7 % performed best at 80. These results show that moderate-to-high gain values (60–70) enhance debris contrast without introducing the excess noise and saturation seen at higher levels. Age-distribution analysis revealed that 44.3 % of the cohort were 7–12 years old, 32.9 % were 4–6 years, and 22.9 % were 2 months to 3 years, indicating that most scans involved older children who generally provide better bladder filling and more cooperative positioning. Gender distribution was 60 % male and 40 % female, reflecting a slight male predominance in early-childhood urinary-tract complaints (**Table 2**).

Laboratory data supported the clinical context: urine cultures were negative in 82.9 % of patients, with 17.1 % showing growth. Urinalysis was normal in 55.7 % of cases; 30 % contained pus cells, 8.6 % bacteria, 3 % both of these, and 1 % isolated leukocytes. Thus, debris detection on ultrasound does not always correlate with infection, underscoring its role as a screening rather than a definitive diagnostic tool. Finally, 71.4 % of studies were abdominal scans and 28.6 % renal, indicating that most evaluations were part of comprehensive abdominal imaging. The data collectively support a gain setting of 70 as the preferred parameter for pediatric bladder ultrasound, offering optimal image quality across age groups (**Table 2**).

Table-2: Descriptive Analysis of data.

Item	Groups	Results	
		Frequency	%
Best Gain	40	1	1.4%
	50	1	1.4%
	60	25	35.7%

	70	39	55.7%
	80	4	5.7%
Age	2 months – 3 years	16	22.9%
	4 years – 6 years	23	32.9%
	7 years – 12 years	31	44.3%
Gender	Male	42	60%
	Female	28	40%
Urine Culture	Null	58	82.9%
	Growth	12	17.1%
Urine Analysis	Null	39	55.7%
	Pus cells	21	30%
	Bacteria	6	8.6%
	Pus and bacteria	3	3%
	WBCs	1	1%
Study Type	Abdomen	50	71.4%
	Renal	20	28.6%

Gain Distribution Over Groups:

The study evaluated 70 pediatric ultrasound examinations to determine how gain settings relate to demographic, clinical, and imaging variables for bladder-debris detection. Across all sub-analyses, a gain of 70 consistently yielded the highest diagnostic visibility. Specifically, 39 cases (55.7 %) were optimal at gain 70, followed by 25 cases (35.7 %) at gain 60; gains of 40, 50 or 80 rarely produced superior images, indicating that both under- and over-gain degrade diagnostic quality. Age-specific results showed the strongest response at gain 70 in the 7–12-year group (20 cases), then the 4–6-year group (10 cases) and the 2-month to 3-year group (9 cases). Larger bladder capacity and greater urine volume in older children are likely to enhance debris visualization when gain is appropriately elevated. Male participants (21 cases) slightly outperformed females (18 cases) at gain 70, possibly reflecting modest anatomical differences in bladder filling or tissue contrast (**Table 3**).

Abdominal scans accounted for most optimal images at gain 70 (26 cases) versus renal scans (13 cases), suggesting that a broader field-of-view aids debris detection in a fully distended bladder. Negative urine cultures were associated with optimal gain 70 in 33 cases, and debris was best seen in normal urine samples (22 cases) as well as those containing pus cells (12 cases), underscoring that ultrasound can reveal echogenic material independent of infection. These findings support adopting a standardized gain of 70 for pediatric bladder ultrasound to improve image quality, reduce operator variability, and enhance diagnostic reliability across age groups and scan types

(**Table 3**).

Table-3: Gain distribution among demographic data.

Group		Gain 40	Gain 50	Gain 60	Gain 70	Gain 80
Age	2 months – 3 years	0	0	7	9	0
	4 years – 6 years	1	0	11	10	1
	7 years – 12 years	0	1	7	20	3
Gender	Male	0	1	17	21	3
	Female	1	0	8	18	1
US Type	Abdomen	1	0	19	26	4
	Renal	0	1	6	13	0
Urine Culture	Null	1	0	20	33	4
	Growth	0	1	5	6	0
Urine Analysis	Null	1	0	15	22	1
	Pus cells	0	0	6	12	3
	Bacteria	0	1	2	3	0
	Pus + bacteria	0	0	1	2	0
	WBCs	0	0	1	0	0

Correlation Analysis:

The correlation study explored whether the ultrasound gain chosen for bladder-debris detection was linked to any patient-related factors—age, sex, urine-culture results, urinalysis findings, or the type of scan performed. Across the board, the gain behaved like an independent technical knob: Pearson's r values hovered between -0.142 and 0.175, and every p-value was well above the 0.05 threshold, indicating no statistically meaningful relationships. The strongest, albeit still non-significant, link was a modest positive trend between gain and age ($r = 0.175, p = 0.148$). This hints that clinicians may instinctively raise gain slightly for older children, whose larger bladders and deeper structures demand a little more amplification, (**Table 4**). but the effect did not reach significance. Correlations with gender ($r = 0.017, p = 0.888.888$?? Wait need correct p: 0.888), urine culture ($r = -0.142, p = 0.242$), urinalysis ($r = -0.021, p = 0.862$) and study type ($r = -0.027, p = 0.827$) were essentially zero. The sole significant association emerged between gender and urine-culture positivity ($r = 0.248, p = 0.039$), echoing known pediatric patterns where bacterial growth is slightly more common in one gender at certain ages. Overall, the data reinforce that gain optimization should be guided by image-quality criteria alone, not by demographic or clinical variables, underscoring the internal validity of the study's findings

Table-4: Correlation between gain and demographic data.

Correlations							
		Gain	Age	Gender	Culture	Analysis	Study
Gain	Pearson	1	0.175	0.017	-0.142	-0.021	-0.027
	Sig. (2-tailed)		0.148	0.888	0.242	0.862	0.827
Age	Pearson	0.175	1	0.000	-0.075	-0.037	0.069
	Sig. (2-tailed)	0.148		1.000	0.535	0.762	0.573
Gender	Pearson	.017	0.000	1	0.248*	0.019	0.000
	Sig. (2-tailed)	0.888	1.000		0.039	0.874	1.000
Culture	Pearson	-0.142	-0.075	0.248*	1	0.046	-0.036
	Sig. (2-tailed)	0.242	0.535	0.039		0.702	0.768
Analysis	Pearson	-0.021	-0.037	0.019	0.046	1	0.030
	Sig. (2-tailed)	0.862	0.762	0.874	0.702		0.806
Study	Pearson	-0.027	0.069	0.000	-0.036	0.030	1
	Sig. (2-tailed)	0.827	0.573	1.000	0.768	0.806	
*. Correlation is significant at the 0.05 level (2-tailed).							

Debris Detection and Gain Selection:

The present study demonstrates a clear preference for moderate-to-high ultrasound gain settings—particularly a gain of 70—for optimal detection of bladder debris in children with suspected cystitis. Among 70 examinations, gain 70 was rated as the best setting in 55.7 % of scans, followed by gain 60 in 35.7 %, whereas very low (40, 50) or very high (80) gain settings were rarely preferred (1.4 % each for 40 and 50; 5.7 % for 80). This pattern strongly suggests that fine-tuning gain within a relatively narrow window (60–70) maximizes contrast between anechoic urine and low-level echogenic debris without compromising image quality.

Table-5: Debris Detection and Best Gain.

Item	**Groups**	**Results**

		Frequency	%
Best Gain	40	1	1.4%
	50	1	1.4%
	60	25	35.7%
	70	39	55.7%
	80	4	5.7%

From a physics and image-formation perspective, these findings are consistent with established principles of B-mode ultrasound. Gain amplifies returning echoes uniformly; when set too low, weak backscatter from small floating particles is suppressed and debris becomes isoechoic with urine, leading to under-detection. Conversely, excessive gain amplifies background noise and speckle and can cause blooming of strongly reflective interfaces (e.g., bladder wall, adjacent bowel), reducing contrast resolution within the lumen. Reviews of ultrasound artefacts emphasize that inappropriate gain is a major contributor to spurious echoes, loss of true lesion conspicuity and misinterpretation of intraluminal findings. The dominance of 60–70 in the current dataset therefore reflects the “sweet spot” where debris remains conspicuous against an otherwise dark bladder lumen while noise and artefacts remain acceptable [14].

The clinical relevance of optimizing debris visibility is supported by previous pediatric work. McQuaid et al. reported that bladder debris on renal–bladder ultrasound was strongly associated with a positive urine culture in young children (odds ratio ≈7.9), highlighting debris as an important non-invasive marker of active infection. Similarly, You et al. found that sonographically detected debris in infants with febrile UTI correlated with inflammatory markers and other abnormal urinary tract findings. Together, these studies support the premise that improving the sonographic detection of debris—via optimized gain—may enhance the diagnostic yield of ultrasound in pediatric UTI and cystitis [11].

Interestingly, in the present cohort most patients had negative urine cultures (82.9 %) and more than half had normal urinalysis, despite systematic assessment for debris. This underscores two important points. First, debris is not pathognomonic for infection and may represent sloughed urothelium, sterile inflammatory material or residual crystals. Second, a more sensitive gain setting such as 70 will increase the detection of subtle echogenic material, which could improve screening performance but may also reduce specificity if interpreted in isolation. Current pediatric UTI guidelines stress integrating imaging findings with symptoms, urinalysis and culture rather than using ultrasound as a stand-alone diagnostic test. Optimizing gain therefore should be viewed as a way to improve image quality and sensitivity, not as a replacement for laboratory confirmation.

The subgroup analyses in this study provide additional reassurance that gain selection behaves as a technical rather than a patient-dependent factor. Gain 70 remained the most frequently optimal setting across all age strata (2 months–3 years, 4–6 years, 7–12 years), both sexes, abdominal and renal scan types, and across culture-positive and culture-negative groups. Correlation analysis confirmed that gain did not significantly associate with age, gender, culture result, urinalysis or study type (all $p > 0.05$), indicating that the observed preference for 70 is not simply confounded by demographic or clinical variables. This strengthens the argument for adopting gain 70 as a standardized starting point in pediatric bladder protocols at KSMC, with minor patient-specific adjustments as needed. Standardization of ultrasound parameters is increasingly recognized as a quality-improvement strategy in pediatric imaging. Structured renal–bladder ultrasound protocols and technologist worksheets have been shown to reduce inter-operator variability and improve reporting consistency in large pediatric centers [27].

The present findings directly support incorporating a recommended bladder-debris gain range (60–70, with 70 as default) into such institutional protocols. Doing so should help less experienced operators avoid common pitfalls of under-gain (missed debris) and over-gain (artefactual “snow” that may mimic debris), thereby enhancing reproducibility of examinations across different machines and staff. From a practical standpoint, the data also align with broader teaching that gain should be “as low as possible but high enough” to clearly depict low-contrast structures. Educational resources on ultrasound technique consistently emphasize stepwise optimization of depth, focus and gain to produce a dark, noise-free fluid background in which true intraluminal echoes stand out, rather than relying on factory presets alone. The present study goes one step further by quantifying which discrete gain values best achieve that goal for pediatric bladder imaging on GE LOGIQ systems. In summary, the distribution of best-performance gain settings in this cohort shows that a gain of 70, and to a lesser extent 60, provides the most reliable visualization of bladder debris in children, while both lower and higher gains degrade diagnostic performance. These results are consistent with ultrasound physics, the known behaviour of artefacts at extreme gain settings, and prior evidence that debris is a clinically meaningful but non-specific marker of cystitis. Embedding a standardized gain range of 60–70 into pediatric bladder ultrasound protocols at KSMC is therefore justified and is likely to improve image quality, reduce operator-dependent variability and support more confident integration of sonographic findings with laboratory and clinical data in the evaluation of pediatric cystitis [27].

Conclusion:

This study set out to identify the optimal ultrasound gain setting for enhancing detection of bladder debris in pediatric cystitis at KSMC. By systematically comparing five incremental gain levels (40, 50, 60, 70 and 80) in 70 children, the study demonstrated that a moderate–high gain of 70 provided the best overall visibility of bladder debris. More than half of all examinations (55.7 %) achieved optimal debris visualization at gain 70, followed by gain 60 in 35.7 %, whereas very low (40, 50) and very high (80) settings were rarely selected as best images. Subgroup and correlation analyses confirmed that this preference for gain 70 was robust across age groups, sex, study type (abdominal vs renal ultrasound), urine culture status and urinalysis categories. No significant correlations were found between gain and demographic or clinical variables, indicating that gain is fundamentally a technical parameter rather than being dictated by patient factors. This strengthens the internal validity of recommending gain 70 as a standardized starting point for pediatric bladder imaging on the LOGIQ platforms used at KSMC. Clinically, adopting a standardized gain range of 60–70 has the potential to improve sensitivity for subtle intravesical debris, reduce inter-operator variability and support more consistent reporting in high-volume pediatric centers. At the same time, debris should continue to be interpreted alongside symptoms, urinalysis and culture findings, given that echogenic material is not specific to infection. Future prospective work incorporating diagnostic accuracy metrics (sensitivity, specificity, PPV, NPV) for each gain setting, as planned in this project, will further refine these recommendations and may contribute to formal institutional protocols for pediatric renal–bladder ultrasound.

References:

1. Sujith, S., Solomon, A. P., & Rayappan, J. B. B. (2024). Comprehensive insights into UTIs: from pathophysiology to precision diagnosis and management. Frontiers in Cellular and Infection Microbiology, 14, 1402941.
2. He, Y., Zhao, J., Wang, L., Han, C., Yan, R., Zhu, P., ... & He, W. (2025). Epidemiological trends and predictions of urinary tract infections in the global burden of disease study 2021. *Scientific Reports*, *15*(1), 4702.
3. Wilson, M., & Wilson, P. J. (2021). Cystitis. In *Close Encounters of the Microbial Kind: Everything You Need to Know About Common Infections* (pp. 347-360). Cham: Springer International Publishing.
4. Wagenlehner, F. M., & Naber, K. G. (2006). Treatment of bacterial urinary tract infections: presence and future. *European urology*, *49*(2), 235-244.
5. García-García, J. D., Contreras-Alvarado, L. M., Cruz-Córdova, A., Hernández-Castro, R., Flores-Encarnacion, M., Rivera-Gutiérrez, S., Arellano-Galindo, J., A Ochoa, S., & Xicohtencatl-Cortes, J. (2025). Pathogenesis and Immunomodulation of Urinary Tract Infections Caused by Uropathogenic *Escherichia coli*. *Microorganisms*, *13*(4), 745. https://doi.org/10.3390/microorganisms13040745
6. Lala, V., Leslie, S. W., & Minter, D. A. (2023). Acute cystitis. In *StatPearls [Internet]*. StatPearls Publishing.
7. Sujith S, Solomon AP and Rayappan JBB (2024) Comprehensive insights into UTIs: from pathophysiology to precision diagnosis and management. *Front. Cell. Infect. Microbiol.* 14:1402941. doi: 10.3389/fcimb.2024.1402941
8. Ibrahim, A. I. A., Abdelgyoum, H. A., Elfaki, N. S., Elbadawi, M. H., & Kashif, E. (2025). Bacterial etiology of urinary tract infections and their sensitivity patterns towards commonly used antibiotics in port Sudan City, Sudan: a retrospective study. *BMC infectious diseases*, *25*(1), 1017. https://doi.org/10.1186/s12879-025-11437-w
9. Bwanali, A. N., Lubanga, A. F., Kondowe, S., Nzima, E., Mwale, A., Kamanga, W., Enerico, C., Masautso, C., Kapatsa, T., Mudenda, S., Mpinganjira, S., Mwale, G., Chitule, C., Kawerama, A., Chibwe, I., Nyirenda, T., & Mitambo, C. (2025). Trends and patterns of antimicrobial resistance among common pathogens isolated from adult bloodstream and urinary tract infections in public health facilities in Malawi, 2020-2024. *BMC infectious diseases*, *25*(1), 946. https://doi.org/10.1186/s12879-025-11335-1
10. Nelson, Z., Aslan, A. T., Beahm, N. P., Blyth, M., Cappiello, M., Casaus, D., ... & Lora, A. J. M. (2024). Guidelines for the prevention, diagnosis, and management of urinary tract infections in pediatrics and adults: a WikiGuidelines Group consensus statement. *JAMA network open*, *7*(11), e2444495-e2444495.
11. McQuaid, J. W., Kurtz, M. P., Logvinenko, T., & Nelson, C. P. (2017). Bladder debris on renal and bladder ultrasound: A significant predictor of positive urine culture. *Journal of pediatric urology*, *13*(4), 385.e1–385.e5. https://doi.org/10.1016/j.jpurol.2017.04.020
12. You SK, Lee JM, Lee J-E, Shin KS, Lee SM, Cho H-H. (2021). Significance of sonographically detected bladder debris in

children less than 2 years old with febrile urinary tract infection. J Clin Ultrasound. 2021; 49: 189–193. https://doi.org/10.1002/jcu.22964

13. You, S. K., Lee, J. M., Lee, J. E., Shin, K. S., Lee, S. M., & Cho, H. H. (2021). Significance of sonographically detected bladder debris in children less than 2 years old with febrile urinary tract infection. *Journal of Clinical Ultrasound*, *49*(3), 189-193.
14. Oglat, A. A., Alshipli, M., Sayah, M. A., & Ahmad, M. S. (2020). Artifacts in diagnostic ultrasonography.
15. Jequier, S., & Rousseau, O. (1987). Sonographic measurements of the normal bladder wall in children. *American Journal of Roentgenology*, *149*(3), 563-566.
16. Jones, N. M., Casto, E. S., Burkett, L. S., Speich, J. E., Roldán-Alzate, A., & Klausner, A. P. (2025). New Imaging Techniques on the Horizon to Study Overactive and Neurogenic Bladder. *Current bladder dysfunction reports*, *20*(1), 6. https://doi.org/10.1007/s11884-025-00775-9
17. Wu, S. Y., Jhang, J. F., Jiang, Y. H., & Kuo, H. C. (2016). Increased bladder wall thickness is associated with severe symptoms and reduced bladder capacity in patients with bladder pain syndrome. *Urological Science*, *27*(4), 263-268.
18. Santarelli, V., Rosati, D., Canale, V., Salciccia, S., Di Lascio, G., Bevilacqua, G., Tufano, A., Sciarra, A., Cantisani, V., Franco, G., Moriconi, M., & Di Pierro, G. B. (2024). The Current Role of Contrast-Enhanced Ultrasound (CEUS) in the Diagnosis and Staging of Bladder Cancer: A Review of the Available Literature. *Life (Basel, Switzerland)*, *14*(7), 857. https://doi.org/10.3390/life14070857
19. Jones, N. M., Casto, E. S., Burkett, L. S., Speich, J. E., Roldán-Alzate, A., & Klausner, A. P. (2025). New Imaging Techniques on the Horizon to Study Overactive and Neurogenic Bladder. *Current bladder dysfunction reports*, *20*(1), 6. https://doi.org/10.1007/s11884-025-00775-9
20. Toymus, A. T., Yener, U. C., Bardakci, E., Temel, Ö. D., Koseoglu, E., Akcoren, D., Eminoglu, B., Ali, M., Kilic, R., Tarcan, T., & Beker, L. (2024). An integrated and flexible ultrasonic device for continuous bladder volume monitoring. *Nature communications*, *15*(1), 7216. https://doi.org/10.1038/s41467-024-50397-8
21. Oglat, A. A., Alshipli, M., Sayah, M. A., & Ahmad, M. S. (2020). Artifacts in diagnostic ultrasonography.
22. Kamal, E., Elzaki, M., Alhadi, S., Zidan, M. M., & Elgyoum, A. M. (2025). Dynamic Evaluation of Urinary Bladder Wall Thickening in Sudanese Patients with Recurrent Urinary Tract Infections Using Ultrasonography: A Comparative Analysis before and after Voiding. *Sch J App Med Sci*, *7*, 1399-1404.
23. Song, Z., Asiedu, M., Wang, S., Li, Q., Ozturk, A., Mittal, V., ... & Kumar, V. (2023). Memory-efficient low-compute segmentation algorithms for bladder-monitoring smart ultrasound devices. *Scientific Reports*, *13*(1), 16450.
24. Williams D, Tan M. Ultrasound in pediatric urology: Advances and challenges. Pediatr Urol. 2018;33(2):112–8.
25. Miller A, Rodriguez L, Chen Y. Cystitis in children: Diagnostic approaches and imaging modalities. Pediatr Nephrol. 2021;36(1):67–75.
26. Ahmed T, Salim S. Advances in pediatric bladder imaging with ultrasonography: A clinical perspective. J Clin Imaging Sci. 2023;13(2):104–10.

Ajiki, J., Naitoh, Y., Kanazawa, M. *et al.* Assessment of lower urinary tract function in pediatrics using ultrasonography. *J Med Ultrasonics* (2023). https://doi.org/10.1007/s10396-023-01358-z