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PAEDIATRIC SURGERY

From Canada to South Africa – the use of artificial intelligence to assist with management decisions in children with hydronephrosis

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Background: Paediatric hydronephrosis (HN) often resolves spontaneously, however some patients with obstructive HN may require surgery to minimise long-term sequelae. Artificial intelligence (AI) could help predict the likelihood of obstructive HN using ultrasound images. This study explores clinician attitudes towards the use of such a tool, developed by a paediatric urology unit in Canada, in their own practice in South Africa (SA).
Methods: Doctors dealing with HN in day-to-day practice were approached to participate. Participants completed a standardised questionnaire, followed by an interview. Here, they were presented with structured questions based on survey responses, as well as unstructured topic areas to explore.
Results: Twenty-three doctors across seven provinces were interviewed, representing specialities including paediatric surgery, urology, general paediatrics, nephrology and radiology. Doctors of all types were open to the use of AI tools to assist with decision-making in children with HN, provided the tool is validated in SA. Discussion themes included concerns around input-image quality and difficulties with imaging access. Several doctors expressed an interest in AI tools that could assist them to better perform their own point-of-care ultrasound (POCUS) and then provide some image analysis, as well as a digital application that allowed the input of various health data points to create a comprehensive referral package for individual nephro-urological patients.
Conclusion: A validated digital tool that incorporates AI to assist with management decisions in children with HN would be potentially welcomed in SA. Barriers include access to high-quality paediatric ultrasound (US) imaging and clinician willingness to adopt new technologies.
Keywords: paediatrics, hydronephrosis, artificial intelligence, machine learning, uteropelvic junction obstruction

Background

Chronic kidney disease (CKD) is a common and costly health condition, a risk factor for cardiovascular disease, as well as a precursor to end-stage renal disease (ESRD).[1-3] Childhood kidney disease has been found to be closely linked with CKD and ESRD in adult life.[2,4] In many cases, advanced CKD can be prevented or mitigated with proactive medical and clinical intervention, especially in childhood. This is possible by close observation, regular monitoring and early intervention when needed.[5,6] Herein, we seek to understand the barriers to and opportunities for developing an ultrasound (US) image-based artificial intelligence (AI) tool to detect and guide the treatment of a common childhood kidney anomaly, hydronephrosis (HN), within the South African healthcare system.

HN is a common prenatal ultrasound finding (1–5% of foetuses) but outcomes for these patients vary widely.[7,8] The majority (70%) of HN resolves without intervention, but medical and/or surgical intervention is indicated to avoid long-term renal damage in patients with an obstructive aetiology such as ureteropelvic junction obstruction (UPJO).[9] In South Africa (SA), the prevalence of paediatric HN is not known, however the incidence of CKD in South African adults is between 15 and 25%,[10] approximately double that of Canada. Because SA is a mixed low- and middle-income country (LMIC), with a two-tier (public/private) healthcare system, services such as comprehensive antenatal care are unevenly distributed and access to this care can be difficult, particularly amongst low-income patients.[1,11-14]

In this environment, HN may only be diagnosed once it becomes symptomatic and there is irreversible functional renal damage.[10] Enabling earlier detection and treatment could potentially result in improved overall renal outcomes for the population. Our collaborative research group has already developed a model to predict obstructive HN based on US images alone for the Canadian context.[15] This

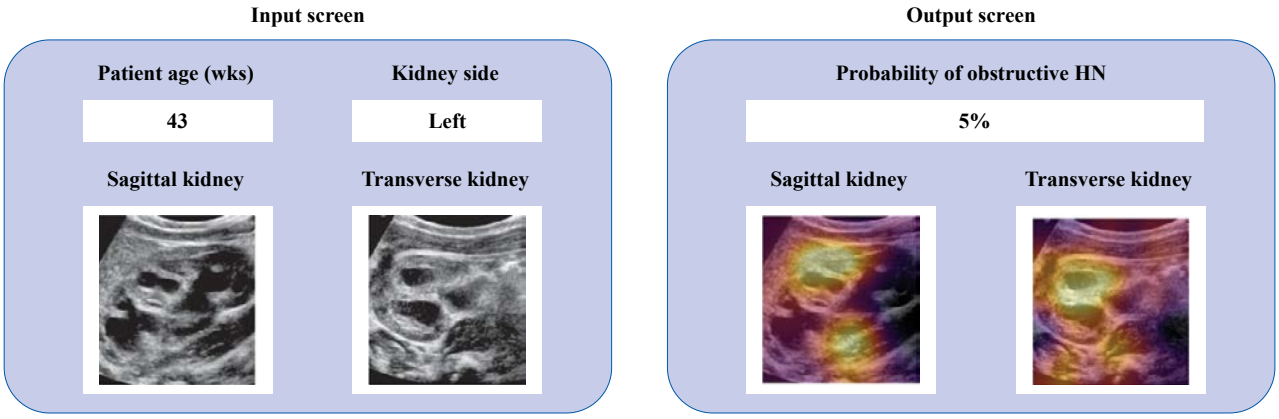

Figure 1: Mock-up of the user interface for an AI application designed to predict the likelihood of obstructive hydronephrosis (HN) based on US images. The 'Input' screen allows the user to upload images and the patient's gestational age and kidney laterality. The 'Output' screen provides a percentage prediction of the likelihood of obstructive hydronephrosis, overlaying a heat-map on the images to allow the user to see which parts of the images were used to make the prediction.

tool, which is still undergoing investigation, examines a kidney US at a single time-point and then makes a prediction regarding the likelihood of obstruction within the hydronephrotic kidney. We have shown that using this tool can reduce invasive testing and follow-up frequency in more than half of patients with non-obstructive HN, without reducing the standard of care for patients with obstructive HN. We hypothesise that a model of this kind could be adapted and used to enable improved HN detection and care in the SA context.[16] A mock-up of the user interface of this tool is shown in Figure 1.

In this exploratory work, we examine how early renal anomalies and dysfunction are identified and treated in the SA healthcare system by interviewing 23 clinicians in varied locations, specialties and career stages. We also explore attitudes towards and perceived challenges around using a Canadian-developed AI tool in the management of paediatric HN in SA. We attempt to establish where opportunities may exist to enhance the use of existing resources and facilitate higher quality care without creating an additional burden for patients, clinicians or the healthcare system. We find important differences in clinical management between the Canadian and South African context. Assumptions in our original HN model based on its development in the Canadian context become clear in this analysis, and opportunities for modifications to the existing tool as well as additional models and technology that have the potential to improve paediatric care are identified.

Methods

Clinicians who would be potentially involved in the management of paediatric HN around SA were approached to participate in the study. For the first round of engagement, clinicians with whom the South African researchers already have an established professional relationship with the authors of this study were approached directly to participate in the process. These 'first-round responders' were each asked to identify one or two potential participants not known personally to the primary researchers who were then approached telephonically or via email to participate. As such, a snowball sampling approach was undertaken to reach the goal number of participants.[17]

Following completion of an informed consent form, participants were asked to complete a REDCap survey to determine participants' demographic details (Table I), to achieve an understanding of their clinical setting and experience, and to get an idea of how frequently and in what role they would interact with patients with HN. Questionnaire responses were then compiled into a spreadsheet and analysed in R v4.0.2 to assess the distribution of participant characteristics.[18] This was followed by an open-ended interview structured to cover various topic areas, including how patients with HN are identified and treated in the interviewees' settings, where technology currently fits into the clinical setting, and viewpoints on AI technology in this context (Appendix A). We recorded and then transcribed the content automatically using Microsoft Office tools, all while being stored within the hospital firewall. Interviews were then coded over two rounds to generate themes for our results.[19,20]

Results and discussion

Study participants

We interviewed 23 doctors across seven provinces. Our participants were between the age of 26 and 55, with eight medical officers, one postgraduate trainee, and 14 specialists. These clinicians were working in the Western Cape (n = 4), Gauteng (n = 9), the Free State (n = 2), the Eastern Cape (n = 5), KwaZulu-Natal (n = 1), the Northern Cape (n = 1) and North West Province (n = 1). Respondents were asked to identify which areas they worked in (they could pick more than one). The field most represented was paediatric surgery (n = 9), followed by general medicine, general paediatrics and nephrology (n = 4 each), urology and neonatology (n = 3 each), radiology (n = 2), and foetal medicine and obstetrics (n = 1 each). Doctors working in the state sector (n = 21), the private sector (n = 9) and academic practice (n = 15) were represented. Three quarters of respondents were based at a hospital 50 km or less from their nearest referral unit.

Detection and management of hydronephrosis

Throughout the interviews, important differences in the clinical presentation of HN in SA versus Canada, where this tool was developed, were highlighted. In both countries, postnatal renal US in asymptomatic patients is most often performed following an irregular finding on a prenatal US.

Table I: Demographic details of participants

Age	25–55 years (mean = 38)
	n (%)
Province of work	
Gauteng	9 (39)
Western Cape	4 (17)
Eastern Cape	5 (22)
Free State	2 (9)
KwaZulu-Natal	1 (4)
North West	1 (4)
Northern Cape	1 (4)
Facility level*	
Quaternary	11 (48)
Tertiary	16 (70)
Secondary	3 (13)
District/primary	1 (4)
Distance to nearest referral centre	
0–50 km	17 (74)
50–100 km	1 (4)
100–300 km	2 (9)
300–500 km	1 (4)
> 500 km	2 (9)
Current position	
Specialist	14 (61)
Postgraduate trainee	1 (4)
Medical officer	8 (35)
Current field*	
Paediatric surgery	9 (39)
Urology	3 (13)
Nephrology	4 (17)
General paediatrics	4 (17)
Neonatology	3 (13)
General medicine	4 (17)
Radiology	2 (9)
Obstetrics	1 (4)
Foetal medicine	1 (4)
Primary role in paediatric HN*	
Diagnosis	17 (74)
Referral	14 (61)
Expectant or medical management	14 (61)
Surgical repair	9 (39)

* participants were able to choose more than one option

Otherwise, it tends to be performed after repeated urinary tract infections (UTIs). In SA, prenatal US is often either unavailable or not reviewed by a specialist. Likewise, UTIs may often go undetected, as fevers may often be treated with antibiotics without the underlying cause being thoroughly investigated. This phenomenon may be driven by the difficulty in obtaining a non-contaminated urine sample from very young children to verify the UTI using a urine dipstick.[21] Additionally, young patients can often not describe their symptoms verbally. Thus, indicators of early renal disease (repeated UTIs and anomalies visible via imaging) may persist for a great deal of time without detection or adequate treatment. Early renal disease is thus relatively "quiet", with subtle features including poor growth and developmental delay being easily missed. Several specialists pointed to this as a problem leading to lower awareness of renal disease relative to more profoundly symptomatic cardiac or neurological issues which have a far more dramatic clinical presentation. One specialist described this issue by saying 'We should have our [blood pressure] and a urine dipstick once a year, the month of your birthday so we don't forget, and that way you'll pick up lots of renal issues because renal is a silent killer. It's a complete nightmare. If you're cardiac, you'll be blue. If you've got epilepsy, you'll be fitting. But the poor old renal kids, they're just cute, they're short, they have a [blood pressure] that's high that no one's ever going to pick up, and they look slightly pale.'

Because US is often not performed on high-risk patients in infancy, our initial model built with early US images would likely require revision to accommodate older patients. Multiple participants stated that awareness of renal disease and accessibility to expertise (easy to access clinical recommendations or correspondence with a specialist) would be valuable in any application built to assess paediatric US (for HN and beyond).

Ultrasound imaging and interpretation

A concern about poor US imaging quality was raised numerous times as a potential barrier to using something similar to our original tool which relies entirely on US images of the kidney. Even quaternary centres may not have specially trained sonographers on staff to perform renal US in paediatric patients. One radiologist interviewed stated that US is the least preferred imaging modality from the perspective of radiologists and is therefore often left for the most junior radiologists to perform, often without much formal training around the modality. US is always user-dependent, and paediatric renal US requires the user to understand that there are some fundamental differences in the appearance of paediatric vs adult kidneys, which may not be well appreciated by radiologists who do not report paediatric US on a regular basis.

Similar to Canada, the clinicians we interviewed who worked at the secondary, tertiary and quaternary centres in SA all used picture archive and communication systems (PACS) to digitally store and access USs. Doctors from one tertiary centre described their ability to view and evaluate ultrasounds from multiple secondary centres which refer to them. However, many interviewees indicated that they rarely view US images and tend to rely heavily on the content of reports for their decision-making. This was due to a combination of junior doctors having very little experience in interpreting US imaging, as well as difficulty accessing images. Several interviewees who worked at a centre with PACS stated that there were very few places in the hospital that allowed the viewing of images. At the primary level USs are often not connected to any kind of storage system and are printed and affixed to a report describing the US which is given either to the clinician or patient – both of which make follow-up and recovery of images challenging. In the worst-case scenario, many sites run out of paper to make physical copies of images on a regular basis, thus leaving no record of these images beyond the written report following the scan. Concerns around the accuracy of reports were also raised: one radiologist interviewed said "I think that there's

a shocking amount of radiology reports that go out [with] mistakes." The accuracy of the report relies on the accuracy of the sonography, both in terms of their sonographic skill and in terms of their dictation.

Given these challenges, several specialists interviewed suggested that an AI tool would need an algorithm to provide internal quality control to identify images that were of too poor quality for reliable interpretation, and to reassure the user that the images provided were acceptable.

Several doctors raised the matter of point-of-care ultrasound (POCUS). Several of them already have some experience with POCUS and use it in their practice on a day-to-day basis. They expressed an interest in a tool that would guide them to capture good renal US images, as well as assist with basic interpretation.

Current use of digital tools and technology

All doctors interviewed indicated that they have ready access to the internet; some have in-hospital Wi-Fi but many use their own data. Most indicated that they would consider it acceptable to use their own data to use a tool such as this, as they already use their data to access other applications for work-related purposes. All of them stated that they mostly use mobile devices and have limited access to a regular desktop, and so any application should be mobile-friendly.

Every doctor we interviewed was familiar with the tools EMGuidance (a medical reference application developed in SA) and Vula, an application which facilitates structured digital referrals. Younger interviewees, in particular, were using these tools in practice. Radiologists we interviewed also used websites such as STATdx and myelination MRI atlas as reference guides to assist their imaging interpretation.[22,23] One senior specialist noted that all clinicians must possess a smartphone because that is how they are paged, making it essentially an unspoken requirement for practice. Doctors reported using messaging tools like WhatsApp to communicate with each other. These tools and the ubiquity of mobile phones were pointed to as a lifeline for younger, less experienced staff who are fielding a wide array of medical issues, particularly before they enter a specialist training programme. This landscape of technology represents a fantastic opportunity to integrate tools where already tech-savvy clinical users access them both in centralised institutions via PACS and in a decentralised fashion via cell phone applications.

Clinician comfort with artificial intelligence

We found the doctors interviewed to be quite familiar with AI algorithms as a concept within and outside the medical sphere. Even those who expressed doubts about the ability to acquire acceptable quality US images from referral centres embraced the effort but noted the need for validation of any tool within the context of its use. That is, no doctors felt comfortable using the HN tool originally described as an off-the-shelf algorithm, but all felt that they would be comfortable using a similar tool that was adapted and validated with South African data, and with permission from their own or referring institution's specialists, or the provincial Health Department in some cases. One interviewee mentioned that they would like to know how users could provide feedback to the algorithm (that is, inform the AI tool that it had made an error).

Numerous respondents felt that a tool such as this would provide them with 'backup' in terms of their own requests and decisions. Doctors at a primary level expressed a belief that their consultations requests might be taken more seriously if accompanied by what would perhaps be perceived as a more objective report from the AI tool, and those at specialist facilities thought that perhaps referring doctors would better accept their feedback, also if accompanied by a report from a validated AI tool.

Conclusion

An AI tool designed to assist with the diagnosis and management of HN would potentially be well received and utilised in SA. The precedent for digital referral pathways has already been set by units and institutions making use of WhatsApp and Vula to facilitate referrals. There is a need to increase awareness of renal disease in children amongst treating clinicians, but, in addition to this, these clinicians would benefit from tools that help them to create structured referrals and prognosticate on their patients. A tool that is able to offer some interpretation of paediatric US images as well as receive inputs on other clinical features including patient history, height, weight, serum creatinine and urine microbiology would potentially assist with this. Clinicians interviewed felt that such a tool would not only help them to better motivate for the transfer of patients requiring tertiary care but would also save some patients from making a long journey to a referral hospital for no reason. We believe that a tool such as this may have a role to play in improving renal outcomes in the South African population.

Improving US acquisition and interpretation also represents a major opportunity for AI models to improve care. Ultrasound-assisted AI technology could have impacts far beyond HN clinical management or renal US alone and could be applied to many other US types and disorders. US is one of the cheapest, least invasive imaging modalities. Tools that make US easier to perform and interpret will empower more junior clinicians, sonographers and radiologists as well as those with less exposure to paediatric patients, in turn, also facilitating communication between these groups.

Study limitations

The current work represents clinicians working in seven of the nine provinces in SA and only one primary care medical officer was interviewed for this study. We believe this limitation is mitigated by the fact that most clinicians interviewed had prior experience working in other provinces as well as interacting with patients and clinicians in other provinces through referrals. In addition, all clinicians above the medical officer level (registrar/fellow, specialist) had completed a year or more of primary care service and spoke to their experiences in this environment.

Another limitation of this work is the focus on clinicians and the clinical environment in isolation of AI and digital tool development in SA. That is, our team's AI expertise is currently solely located in North America, thus leading to the potential for "offshoring" of future computational work. Therefore, future work will engage with data scientists and technical experts within SA to build toward more sustainable tool development, deployment and maintenance.

In conclusion, medical practitioners are generally enthusiastic about the potential utility of an AI tool to assist with the diagnosis and management of children with HN

in SA, provided the tool was validated for the SA context. Potential limitations to the use of such a tool include the quality of available imaging and getting broad-based 'buy-in' on both the referring and receiving end of the patient pathway. The further development, validation and clinical integration of these tools into new and existing applications have the potential to measurably improve outcomes for at-risk patients.

Conflict of interest

The authors declare no conflict of interest.

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Ethical approval

Ethical approval for this study was obtained from the Human Research Ethics Committee at the University of the Witwatersrand (Protocol number: M211119) and the Research Ethics Board at the Hospital for Sick Children (REB number: 1000079335).

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Appendix A

Interview to be conducted via Zoom – pilot topic areas and questions

Clinical setting

Here we wanted to unpack the experience of clinicians who see these patients. First, we demonstrate our AI tool that was built to assist with HN clinical management.

This will help us gauge how they view HN as an issue, given their clinical setting, and thus how as well as whether they would use a tool of this kind:

- Is HN front-of-mind here?
- If HN is considered a problem, how is it being thought about?
- Do you currently use digital tools for your clinic?
- If you had infinite choice, what would be the ideal AI/digital tool for your clinic?
    - Tools that assist with diagnosis? Therapy options? Follow-up/referral pathways?
- What reservations would you have with using an AI/digital tool?
    - Do you see any issues with using a tool that interprets ultrasound to stratify high- vs low-risk HN patients? (E.g., from the perspective of your patients and practice or in terms of clinical loads for yourself or others.)
    - Do you think you would ever consider using one of these tools, not necessarily just for hydro, but for other conditions also?
        - If not, why not, what more would you want to know, what reservations do you have?
        - Do you feel that the tool would be very unlikely to contribute to your process?
        - Do you have moral or ethical reservations regarding artificial intelligence? (E.g., privacy, data ownership, model getting it wrong, etc.)
        - Do you think it would be too complicated to use or add too much extra time to the clinical contact session, etc.?
    - Do you think that even if you do not use the tool for your decision-making process, that it would be useful for clinicians who need to refer to you?
    - Do you think it would be practical for district-level practitioners to use a tool like this to guide them regarding next steps once presented with a patient with hydronephrosis?
    - What would you like to see in a tool like this?

Technology access

Here we wanted to better understand the current technological capabilities and practices in different clinical settings. This will help us to better understand (1) how an AI tool would ideally be delivered (i.e., phone/internet/etc.) and (2) what kinds of upgrades may work to better enable these tools (i.e., ultrasound machine/probe, data storage):

- Is Wi-Fi reliably available?
- Are there smart phones? What kind(s)?
- Desktop/laptop computers? What kind(s)?
- Data storage? What kind(s)?
- Ultrasound machines available? What kind(s)?
    - What kind of ultrasound images (paper image, computer file, etc.) are you getting and how are they stored?