# BARRIERS AND OPPORTUNITIES TO IMPROVE RENAL OUTCOMES IN SOUTH AFRICA USING AI TECHNOLOGY FOR PEDIATRIC ULTRASOUND INTERPRETATION

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## ABSTRACT

Over 10% of the global population is affected by chronic kidney disease (CKD) and those without preventative care and early intervention are the worst impacted. Many childhood precursors to CKD such as hydronephrosis (HN) continue to be detected and treated late in low- and middle-income countries where prenatal and early-life ultrasound is less common. Artificial intelligence-based technology holds promise for improving some of this detection and treatment. In this work, we explore the promise and pitfalls of transferring an AI-based tool for early HN detection in pediatric ultrasound from Canada, where it was developed and validated, to South Africa. We explore challenges and opportunities at the health-system-, institutional-, and provider-levels that using this technology in this new clinical environment involve. Our investigation is performed through interviews with clinicians at various levels, locations, and in different specialties. We find that the context of our tool's use will change in terms of both clinicians and patients, as the users of our tool in South Africa will have less access to pediatric sonography expertise and, for related reasons, patients will tend to be older when they receive an ultrasound imaging. These differences imply the need for adaptation of both the underlying algorithm as well as the tool's interface for successful deployment in this setting. However, given these revisions, the clinicians interviewed are eager for AI-based assistance in caring for these patients earlier and more effectively and believe algorithms of this kind will be useful for improving care.

## 1 INTRODUCTION

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), in which an individual's kidneys are failing and dialysis or organ transplant is requiredBikbov et al. (2020); Golestaneh et al. (2017); Silva et al. (2018). In many cases, advanced CKD can be prevented or mitigated with medical and clinical intervention, particularly early on when damage is mildLuyckx et al. (2020); Becherucci et al. (2016). Therefore, as expected, the burden of CKD is much higher in lower-income countries and among low-income populations of high-income countries, where access to comprehensive medical screening and care may be difficult Bikbov et al. (2020); Fored et al. (2003); Bello et al. (2008). Childhood kidney disease has been found to be closely linked with CKD and ESRD later in adult life thus damage to the kidneys and urinary tract in childhood leads to far more severe and costly health outcomes later in life Calderon-Margalit et al. (2018); Golestaneh et al. (2017). This work seeks to understand the barriers and opportunities of developing an ultrasound image-based AI tool to detect and guide the treatment of a common childhood kidney anomaly, hydronephrosis (HN), in the South African healthcare system.

Hydronephrosis (HN, dilation of the kidney) is a common prenatal ultrasound finding (1-5% of fetuses) but outcomes for these patients vary widely Sinha et al. (2013); Ek et al. (2007). The majority (70%) of these patients resolve without intervention while the remainder require medical and/or surgical intervention to avoid long-term renal damage Dos Santos et al. (2015). In North

America, invasive tests and ultrasound are performed and reviewed by specialists in repeated clinic visits from birth or early in life to determine if a given case of HN requires medical or surgical intervention. Meanwhile, in South Africa, the prevalence of HN is not known, however the incidence of CKD in South African adults is between 15 and 25% Matsha et al. (2013), approximately double that of Canada. Because South Africa is a mixed low- and middle-income country (LMIC), with a two-tier (public/private) healthcare system, services such as routine antenatal care can limited or poorly accessed, particularly by low-income patients International (2014); Sibiya et al. (2018). HN is often only diagnosed once it becomes symptomatic and irreversible functional damage to the kidney has been done Matsha et al. (2013). Therefore, enabling earlier detection and treatment could likely lead to less costly and less invasive interventions with improved overall renal outcomes for the population.

Our collaborative research group has already developed a model to predict obstructive HN based on ultrasound images alone for the Canadian context Erdman et al. (2020). This work and our on-going investigation of this tool showed that we could reduce invasive testing and follow-up frequency in more than half of patients with hydronephrosis that will resolve on its own without reducing the standard of care for patients with obstructive hydronephrosis by examining a kidney ultrasound at a single time-point. We hypothesize that a model of this kind could be adapted and used to enable improved HN detection and care in the South African context with less initial data and infrastructure than developing a model from scratch Curth et al. (2019). South Africa is a particularly salient place to focus on HN since children aged 0 - 14 make up almost a third of the population of around 58 million and early childhood is the ideal time to detect and intervene on this condition Africa (2012); Kaspar et al. (2016). Therefore, the potential to improve outcomes and overall quality of life for children with early CKD markers, such as HN, represents a profound development opportunity.

In this work, we explore how early renal anomalies and dysfunction are identified and treated in the South African healthcare system by interviewing 15 clinicians in different locations, specialties, and stages of their career. In these interviews we hone in on where opportunities may exists to enhance the use of existing resources and facilitate higher quality care without additional burden on patients, clinicians, and 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 are likely to improve pediatric care are identified.

## 2 METHODS

This paper aims to explore and understand the challenges and opportunities to improve renal outcomes by adapting a Canadian AI tool for HN detection to the South African clinical environment. We investigate this research question from the perspective of clinicians who currently work with HN patients in South Africa by conducting surveys and interviews with this group.

### 2.1 PERSPECTIVES ASSESSED IN THIS WORK

We issued a structured questionnaire and then conducted semi-structured interviews with clinicians in South Africa regarding their views on the health-system-, institution-, practitioner-, and patient-level consequences of using an AI model to assist with clinical decision making, using obstructive HN as a specific example Gill et al. (2008). We first collected responses in a structured survey to participants and followed this with a linked, unstructured interview assessing multiple topic areas.

Structured interview questions based on survey responses were paired with unstructured topic areas which we explore with the participants. To generate our topic areas and questions, we first piloted a set of questions to determine the demographic details of our interviewees, 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 hydronephrosis. We expected trainees, surgeons and physicians to have slightly differing views, and that decision making may vary depending on the clinician setting (public vs private). We planned to recruit approximately 12 clinicians Guest et al. (2006). Around 50% of these recruits would have private-sector experience in addition to the work they have done in state facilities. We aimed to recruit participants who are clinicians involved in pediatric care who are or were previously affiliated to academic training hospitals in South Africa.

The pediatric surgical and nephrological community in South Africa is intimate, and 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 responders not known personally to the primary researchers to also participate. As such, a snowball sampling approach was undertaken to reach the goal number of participants Goodman (1961). Potential participants were approached via telephone or email to provide information about the study and to offer a time for discussing the study, consent form (emailed to potential participants after initial response to the first email), and an opportunity to ask questions. Following consent, participants were asked to fill out a RedCap survey detailing their clinical background to better contextualize their perspectives relative to management of HN (Appendix B) Wright (2016). Questionnaire responses were then compiled into a spreadsheet and analysed in R v4.0.2 to assess the distribution of participant characteristics Ihaka & Gentleman (1996).

We then conducted our semi-structured interviews to better understand how HN patients are treated, where technology currently fits into the clinic, and viewpoints on AI technology in this context (Appendix C). 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 Support (2021); Stuckey (2015). These methods were reviewed and approved by the internal review board of Nelson Mandela Children's Hospital.

## 3 RESULTS

### 3.1 STUDY PARTICIPANTS

We interviewed 15 clinicians (11 women, 4 men) across 4 provinces. Our participants were between the age of 26 - 55, with 6 medical officers, 1 fellow/registrar, and 8 specialists. These clinicians were working in the Western Cape (n = 3), Gauteng (n = 8), the Free State (n = 1), and the Eastern Cape (n = 3). Of the specialists interviewed, the most represented were pediatric surgeons (n = 5), followed by nephrologists (n = 4), general medicine (n = 4), radiology (n = 2), general pediatrics (n = 2), neonatology (n = 1), and obstetrics (n = 1). The clinicians interviewed represent those working in state practice only (n = 6), state practice and academic practice (n = 2), private practice and academic practice (n = 1), as well as those working in private, state, and academic practice simultaneously (n = 6).

### 3.2 DETECTION AND MANAGEMENT OF HYDRONEPHROSIS

Throughout the interviews, important differences in how HN is managed in South Africa versus Canada, where this tool was developed, were highlighted. In both countries, postnatal renal ultrasound is most often performed following an irregular finding on a prenatal ultrasound or after repeated postnatal urinary tract infections (UTI). However, in South Africa, prenatal ultrasound is often either unavailable or not reviewed by a specialist. Likewise, UTIs often will go undetected, rather treated as fevers with antibiotics without the underlying cause being investigated. This phenomenon is driven by the difficulty in obtaining a non-contaminated urine sample from very young children to verify the UTI using a urine dipstick Diviney & Jaswon (2021). In addition, these patients often cannot describe their symptoms verbally (¡ 2 years old). Therefore these indicators of early renal disease (repeated UTIs and anomalies visible via imaging) can often continue for a great deal of time without detection or adequate treatment.

Renal disease is thus relatively "quiet" early on, manifesting as a child being shorter, paler, perhaps slightly neurocognitively delayed. 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 it 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." Therefore, because early renal ultrasound is often not performed on these patients, our initial model built with early ultrasound images would likely require revision to accommodate older patients. Interviewees also noted that awareness of renal disease and accessibility to expertise (easy to access clinical recommendations or correspondence with a specialist) should accompany any application built to assess pediatric ultrasound (for HN and beyond).

### 3.3 ULTRASOUND IMAGING AND INTERPRETATION

Poor ultrasound imaging quality was brought up as a barrier to using anything like our original tool (which entirely relied on ultrasound images of the kidney) in almost all of our interviews. Even in most quaternary centers, there will only sometimes be a dedicated or specially trained sonographer on staff to perform renal ultrasound in pediatric patients. Indeed, one radiologist interviewed even pointed out that ultrasound is the least preferred imaging modality from the perspective of radiologists and is therefore often left for the most junior radiologists to perform. This perspective is clearer when considering what ultrasound entails versus an MRI or CT, particularly in a young (¡5 yrs old) child. Scans from MRI and CT require the patient to lie still, therefore young children are often sedated or systematically distracted (with soothers, video, goggles) for this procedure.Koch (2008) Ultrasound, on the other hand, is most often performed directly on the abdomen of an alert child/baby who may be wiggling or even crying with his or her guardian next to them. The radiologist/sonographer must then navigate the 3 dimensional space of the abdomen and from that information, determine the presence of a wide array of different anomalies and conditions. This is made even more challenging if one rarely sees young children, as there are systematic differences in the normal presentation of kidneys (and other organs) in children as they age and they are also, therefore distinct from adult anatomy beyond just being much smaller. Therefore, it is unsurprising one radiologist noted "[ultrasound] gets kind of shoved on the junior laps so you get a feel that it's something that should be easy and that a junior can do. But I really think it's just people hating doing it."

Meanwhile, ultrasound reports from radiologists are heavily relied upon, particularly for less experienced clinicians. Multiple medical officers interviewed noted that they completely rely on the written radiology report to guide their decision-making, referring to it as the "gold standard." However, one radiologist interviewed said "I think that there's a shocking amount of radiology reports that go out [with] mistakes." That is, those producing the so-called "gold standard" are not confident in their determinations. Given these challenges, one specialist interviewed suggested the use of internal quality control of the images in the algorithm, to detect images which cannot be used for prediction. Several more junior clinicians expressed interest in user-guidance to enable improved collection of the ultrasound images as well as tools to double check or flag potential imaging findings.

Similar to Canada, the secondary, tertiary, and quaternary centers the clinicians we interviewed worked at in South Africa all used picture archive and communication systems (PACS) to digitally store and access ultrasounds. Indeed, clinicians from one tertiary care center described their ability to view and evaluate ultrasounds from multiple secondary centers which refer to them. At the primary level, however, ultrasounds are often not connected to any kind of storage system. Images are printed and stapled to a report describing the ultrasound which is either given to the clinician or patient – both of which result in follow-up and recovery of these images to be very challenging. This is a particular issue when considering that most sites will run out of paper to make physical copies of images within 6-8 months of a new fiscal year, thus leaving no record of these images beyond the written report following the scan.

### 3.4 CURRENT USE OF DIGITAL TOOLS AND TECHNOLOGY

Every clinician we interviewed was familiar with the tools EMGuidance, a medical reference application, and Vula, an application to facilitate structured, digital referrals. Some, particularly younger interviewees were using these tools in practice. The radiologists we interviewed also used websites like STATdx and myelination MRI atlas as reference guides to assist their imaging interpretation Ekins (2007); Singh et al. (2015). One senior specialist noted that all clinicians must have a smart phone because that is how they are paged, making it essentially an unspoken requirement for practice. In addition, clinicians reported often using messaging tools like WhatsApp to communicate with specialists or as specialists. 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 are specialized. This landscape of technology represents fantastic opportunity to integrate tools where already tech-savvy clinical users access them both in centralized- institutions via PACS and decentralized-fashion via cellphone applications.

### 3.5 Clinician comfort with AI

We found the clinicians 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 high enough quality ultrasound images from referral centers embraced the effort and noted the need for validation of any tool within the context of its use. That is, no clinicians felt comfortable using the HN tool originally described as an off-the-shelf algorithm but all clinicians felt that they would be comfortable using a similar tool that was adapted and validated with data from their institution or those they refer to.

## 4 Discussion

We find ideal points of integration within or adjunct to already utilized applications for referral, medical guidance, and messaging between clinicians. In addition, increasing awareness of early kidney disease and enabling more structured communication between primary/secondary clinicians and pediatric specialists should be prioritized to improve renal outcomes through and in addition to these tools. Finally, improving ultrasound acquisition and interpretation represents a major opportunity for AI-models to improve care. Ultrasound-assistant AI technology could have impacts far beyond HN clinical management or renal ultrasound alone and could be applied to many other ultrasound types and disorders. Prior data shows that clinicians with less experience performing and interpreting pediatric ultrasound produce less accurate reports and our own interviews point to ultrasound being difficult to use and interpret, particularly for younger pediatric patients Castro et al. (2019). However, ultrasound is one of the cheapest, least invasive imaging modalities. We believe tools to make ultrasound easier to perform and interpret will empower more junior clinicians, sonographers, and radiologists as well as those with less exposure to pediatric patients, in turn, also facilitating communication between these groups.

### 4.1 Limitations

The current work represents clinicians working in only 4 of the 9 provinces in South Africa 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) have completed a year of primary care 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 South Africa. 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 South Africa to build toward more sustainable tool development, deployment, and maintenance.

### 4.2 Conclusion

There is ample opportunity for AI-base tools to be integrated into the clinical management of patients with HN and beyond in South Africa. 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 of all kinds.

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# A Appendix

# B Pre-interview questionnaire

- How often do you see pediatric patients with hydronephrosis?
  1. Never
  2. Less than once a year
  3. A few times a year
  4. Once a month
  5. Every Week

- When you see a patient with hydronephrosis, what are your primary roles? (can select more than one):
  1. Diagnosis
  2. Referral
  3. Expectant or medical management
  4. Surgical repair
- Year of birth
- Current position
  1. Specialist
  2. Post-graduate trainee (registrar)
  3. Medical officer
  4. Medical student
- Current field (can select more than one):
  1. Urology
  2. Pediatric Surgery
  3. Nephrology
  4. General Pediatrics
  5. Neonatology
  6. General medicine (including GP practice)
  7. Radiology
  8. Obstetrics
  9. Fetal medicine
- Type of practice (can select more than one):
  1. Private Practice
  2. State Practice
  3. Academic Practice
- Level of the health care facilities you work at (can select more than one):
  1. Quarternary
  2. Tertiary
  3. Secondary
  4. District/Primary
- Which province do you work in?
  1. Gauteng
  2. Western Cape
  3. Free State
  4. Kwazulu Natal
  5. Eastern Cape
  6. Limpopo
  7. Mpumalanga
  8. North West Province
  9. Northern Cape
- Would you describe the place where you work as:
  1. Urban
  2. Suburban
  3. Semi-rural
  4. Rural
- How far away do you think your nearest referral service that would manage patients with hydronephrosis is?

1. 0 - 50km
2. 50 - 100km
3. 100 - 300km
4. 300 - 500km
5. ¿500km

# C Semi-structured interview topic areas and questions

## C.1 Clinical Setting

Here we wanted to unpack the experience of clinicians who see HN patients. This helped 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:

- How often do you see patients with HN in your practice and in what capacity do you interact with them?
- Do you currently use digital tools for clinical management?

## C.2 Technology access

Here we wanted to better understand the current technological capabilities and practices in different clinical settings. This will help us 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 wifi available?
- Do you and your colleagues have/use smart phones?
- Are desktop/laptop computers available? What kinds? To whom?
- How is ultrasound and clinical data stored?
- What kinds of ultrasound machines are available?
- How is data from these machines delivered to the patient/other clinicians?

## C.3 Viewpoint toward AI

Last, we wanted to understand how clinicians view AI and digital tools within their practice and more generally, with an opportunity to highlight any reservations they may have.

- What reservations would you have with using an AI/digital tool?
  - If not, why not, what more would you want to know, what reservations do you have?
  - Do you feel the tool would be likely 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?
- 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?