Predicting obstructive hydronephrosis from 1-2 ultrasound images

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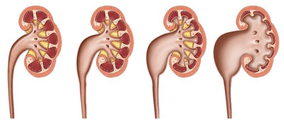
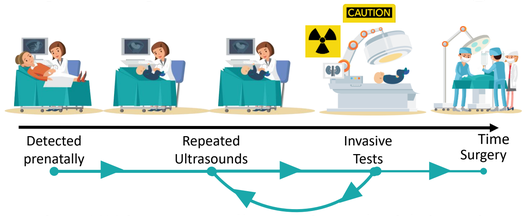
What is hydronephrosis?



Healthy Kidney → Hydronephrosis (HN) Kidney

Urinary tract dilatation found in up to 5% of fetuses.[1]

How is hydronephrosis clinically managed?

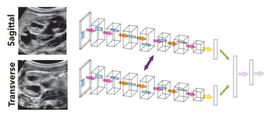


After detection, HN is postnatally monitored with imaging every 3-6 months. Surgery occurs in 10-30% of cases.[2]

Our goal

Reduce the invasiveness of clinical management for hydronephrosis.

Our model



P(obstruction) = 1%

We use a Siamese CNN to classify obstructive hydronephrosis with 2 still ultrasound views: sagittal and transverse.[3]

Our data

	SickKids Training		SickKids Prospective Test		Stanford		UIowa		CHOP	
	No obs	Obs	No obs	Obs	No obs	Obs	No obs	Obs	No obs	Obs
Total ultrasounds	1621	317	636	75	246	27	20	56	29	57
Unique individuals	307	96	174	28	92	10	20	56	29	57
Sex										
Male	1307	243	530	69	180	24	17	42	17	37
Female	314	74	106	6	66	3	3	14	12	20
Age group										
< 2 yrs	1418	308	561	71	0	0	19	49	15	19
2-5 yrs	143	9	72	0	244	27	1	6	5	5
>5 yrs	60	0	3	3	2	0	0	1	9	33

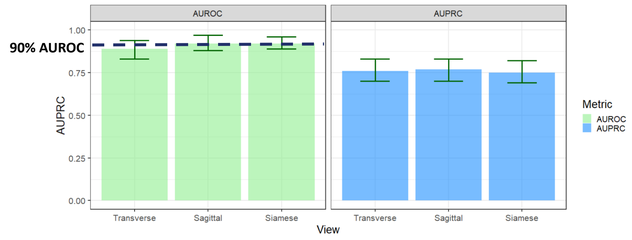
Obs = Obstruction; Stanford = Stanford Children's Health – Lucile Packard Children's Hospital;
UIowa = University of Iowa Stead Family Children's Hospital; CHOP = Children's Hospital of Philadelphia

Citations

1. Nguyen et al. SFU consensus statement on the evaluation and management of HN. (2010). Ped Urology
2. Fernbach et al. Ultrasound grading of hydronephrosis: introduction to the system used by the SFU. (1993). Ped Urology
3. Erdman et al. Predicting obstructive hydronephrosis based on ultrasound alone. (2020). MICCAI

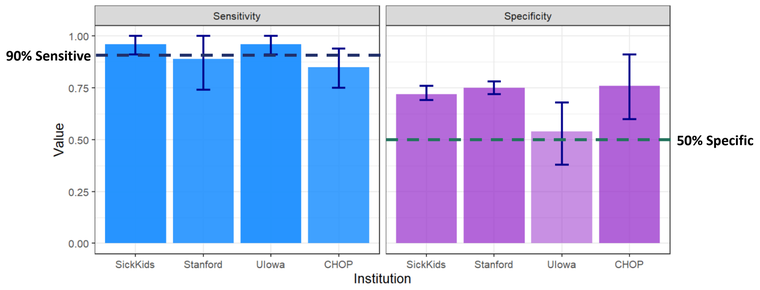
Evaluation of our model

Retrospective testing: same institution



Sagittal and Siamese model show > 0.9 AUROC.
No significant differences in model AUROC or AUPRC.

Retrospective testing: different institutions



SickKids model performance in data from different pediatric hospitals across North America. All near 90% sensitive, >50% specific.

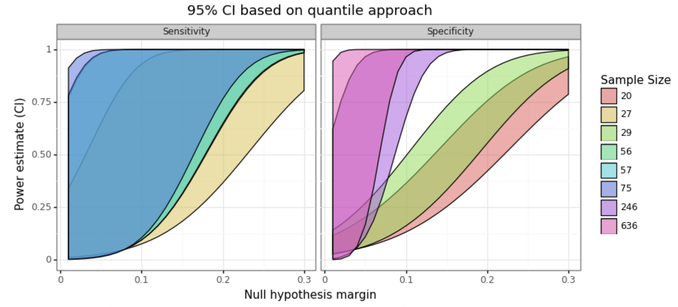
Prospective testing: same institution, targeting 90% sensitivity

Low risk to obstructed patients	Sensitivity (n = 28)	Specificity (n = 174)	Positive Predictive Value	Negative Predictive Value	High certainty for model-identified non-obstructed cases
	0.96 (0.91, 1.0)	0.72 (0.69, 0.76)	29%	99%	

Prospective test of Siamese model in SickKids samples results in safe (sensitive > 90%) and effective (specific > 50%) prediction.

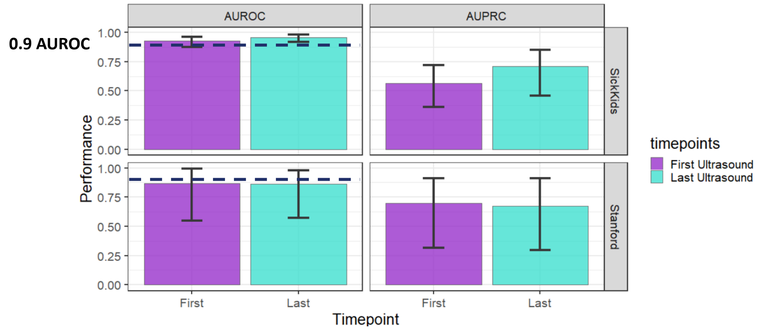
50% reduction in nuclear scans for non-surgical patients

Power for model sensitivity and specificity

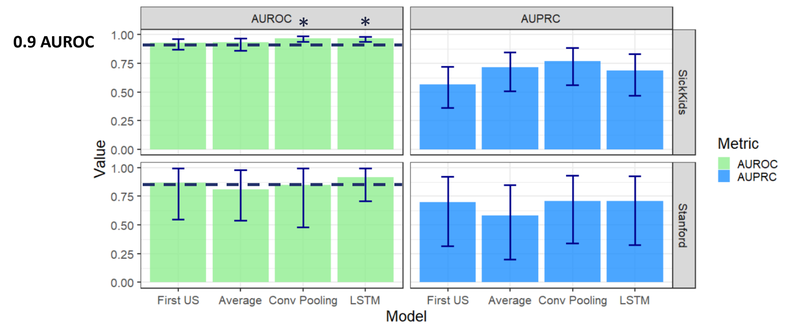


Contextualizing power of sensitivity and specificity tests in prospective data and data from other institutions based on retrospective SickKids data.

Cross-sectional model compared to longitudinal model



Model performance in first and last ultrasound not significantly different. Stanford bounds near vacuous.



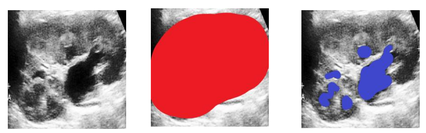
Convolutional pooling and LSTM modeling of the ultrasounds results in significantly better performance for SickKids but all models >0.9 AUROC.

Discussion

Preliminary results show strong, generalizable predictive performance.
More data needed for evaluation beyond SickKids.

Next steps

More data for CHOP, UIowa, Stanford: testing, fine-tuning, segmentation
Point-of-care ultrasound
Primary care testing
Health economic evaluation



Original | Kidney | Hydronephrosis

Impact

Reduction in repeated and invasive tests in young (< 5 yrs) patients.
Reduced necessity for patients and families to travel to hospital.

Conclusions

Obstructive HN reliably predicted from ultrasound images alone at any timepoint.

Acknowledgements

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