Supplementary Material

Diagnostic Accuracy of Point-of-Care Ultrasound versus Neck Radiography for Laryngotracheal Stenosis: Complementary Roles in a Resource-Limited Triage Pathway

Supplementary Material 1: STARD 2015 Checklist

Section & Topic	Item #	STARD 2015 Item	Location in Manuscript
TITLE OR ABSTRACT			
Identification as a study of diagnostic accuracy	1	Identify the study as a diagnostic accuracy study (at least one measure of accuracy, e.g., sensitivity, specificity, AUC).	Title contains "diagnostic accuracy"; Abstract reports sensitivity, specificity, AUC.
ABSTRACT			
Structured summary	2	State research questions/aims, methods, results, and conclusions.	Abstract (Background, Methods, Findings, Interpretation, Funding).
INTRODUCTION			
Scientific/clinical background	3	State research questions/aims, including intended use and clinical role of index tests.	Introduction, paragraphs 3–5 (clinical need for triage tools in LMICs).
Study objectives/hypotheses	4	State aims/hypotheses for estimating or comparing diagnostic accuracy.	Introduction, final paragraph (explicit aims: compare POCUS vs XR, assess anatomical subsites, propose triage algorithm).
METHODS			

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Study design	5	Specify whether data collection was planned before index tests and reference standard (prospective vs retrospective).	Methods: Study design and setting – "This prospective diagnostic accuracy study".
Participants	6	Describe eligibility criteria.	Methods: Participants – inclusion/exclusion criteria (age ≥12, suspected LTS, exclusions).
	7	Describe setting, locations, and dates of data collection.	Methods: Study design and setting – Frere Hospital, South Africa; 1 Jan 2023 – 31 Dec 2025.
	8	Describe participant recruitment.	Methods: Participants – "Consecutive patients referred for clinically indicated neck CT".
	9	Describe whether participants formed a consecutive, random, or convenience series.	Methods: Participants – "Consecutive patients".
Test methods	10a	Describe index test in sufficient detail to allow replication.	Methods: Index test 1 (POCUS) and Index test 2 (XR) – full protocols, equipment, planes, measurements.
	10b	Describe reference standard in sufficient detail to allow replication.	Methods: Reference standard: Multidetector CT – scanner, parameters, reconstructions, measurements.
	11	Describe rationale for choosing reference standard.	Methods: Reference standard: Multidetector CT – paragraph 2 (ethical/pragmatic reasons: CT as non-invasive surrogate for LTB).
	12a	Define and justify test positivity cut-offs/categories for index test (pre-specified vs exploratory).	Methods: Definition of stenosis and test positivity – ≥50% luminal narrowing (Cotton-Myer grade II+); indeterminate criteria defined.
	12b	Define and justify test positivity cut-offs/categories for reference standard.	Methods: Definition of stenosis and test positivity – ≥1 SD below sex-specific mean (≥50% narrowing).

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	13a	Were index test results interpreted without knowledge of reference standard?	Methods: Blinding – POCUS and XR readers blinded to CT.
	13b	Were reference standard results interpreted without knowledge of index test results?	Methods: Blinding – Second radiologist interpreting CT was fully blinded to POCUS, XR, and all clinical information.
	14	Describe any clinical information available to test operators.	Methods: Blinding – operators blinded to other test results; clinical suspicion noted but not shared during interpretation.
Analysis	15	Describe methods for calculating or comparing diagnostic accuracy and quantifying uncertainty (e.g., 95% CI).	Methods: Statistical analysis – sensitivity, specificity, PPV, NPV, LR+, LR–, AUC, DeLong test, McNemar, weighted kappa, exact binomial CIs.
	16	Describe methods for calculating test reproducibility, if done.	Methods: Index test 1: POCUS – inter-operator reproducibility assessed in subset of 50 participants.
	17	Report number of participants and flow using a diagram; report recruitment dates.	Results: Figure 1 (STARD flow diagram); dates in Methods.
	18	Report demographic and clinical characteristics of participants.	Results: Table 1 (age, sex, symptoms, history).
	19	Report number of indeterminate results and how they were handled in analysis.	Results: Technical feasibility – indeterminate POCUS (n=37) and XR (n=3) reported; handled per per-protocol (excluded) and sensitivity analysis (reclassified as negative).
	20	Report distribution of disease severity and alternative diagnoses.	Results: Prevalence 66.9% (CT-confirmed); alternative diagnoses not listed (cohort defined by suspected LTS).
Test results	21	Report cross-tabulations of index test results by reference standard results.	Supplementary Tables S2 and S3 – 2×2 tables for POCUS vs CT and XR vs CT.

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	22	Report any adverse events from index tests or reference standard.	Results – none reported (manuscript states no adverse events).
Estimates	23	Report estimates of diagnostic accuracy with precision (95% CI).	Results: Table 3 (composite); Table S6 (anatomical subsites); Table S7 (detailed by plane).
	24	Report how indeterminate results, missing responses, outliers were handled.	Methods: Definition of stenosis… (indeterminate criteria); Results: Sensitivity analysis – reclassification as test-negative (Supplementary Table S4).
	25	Report estimates of variability of diagnostic accuracy between subgroups (e.g., anatomical regions, readers).	Results: Anatomical subsite analysis – Table S6, Figure 3; Inter-observer agreement – Table S5 (weighted kappa by region).
	26	Report estimates of test reproducibility, if done.	Results: Table 2 (inter-operator reproducibility).
DISCUSSION			
Implications	27	Discuss clinical applicability of findings.	Discussion – Clinical and health systems implications; Figure 5 – proposed anatomically-guided triage algorithm.
OTHER INFORMATION			
Supplementary findings	28	Mention study registration number and registry name.	Methods: Participants (ethical approval paragraph) – PACTR202510808811458; also in Abstract.
	29	Provide statement on where study protocol can be accessed.	Declarations: Data sharing – Mendeley DOI provided; protocol available from corresponding author on reasonable request.
	30	Provide information about funding and role of funders.	Declarations: Funding – None; Methods: Role of the funding source – "There was no funding source for this study."

AUC = area under the curve; CI = confidence interval; CT = computed tomography; LTS = laryngotracheal stenosis; PACTR = Pan African Clinical Trials Registry; POCUS = point-of-care ultrasound; STARD = Standards for Reporting Diagnostic Accuracy Studies; XR = neck radiography.

Supplementary Material 2: Composite Diagnosis of Laryngotracheal Stenosis (≥50% luminal narrowing): POCUS versus CT

	CT Positive	CT Negative	Total
POCUS Positive	91	3	94
POCUS Negative	8	46	54
Total	99	49	148

CT = computed tomography; POCUS = point-of-care ultrasound.

Supplementary Material 3: Composite Diagnosis of Laryngotracheal Stenosis (≥50% luminal narrowing): XR versus CT

	CT Positive	CT Negative	Total
XR Positive	93	1	94
XR Negative	6	48	54
Total	99	49	148

CT = computed tomography; XR = neck radiography.

Supplementary Material 4: Diagnostic Accuracy of Point-of-Care Ultrasound (POCUS) for Cricoid Arch Thickness Assessment

Metric	Value (95% CI)
Sensitivity	77.97% (65.27–87.71%)
Specificity	91.01% (83.06–96.04%)

Metric	Value (95% CI)
AUC	0.845 (0.776–0.899)
Positive Likelihood Ratio	8.67 (4.42–17.03)
Negative Likelihood Ratio	0.24 (0.15–0.39)
Accuracy	85.81% (79.13–91.00%)
Weighted Kappa	0.207 (0.081–0.332)

Diagnostic accuracy and inter-rater agreement of POCUS for detecting abnormal cricoid arch thickness compared with computed tomography (CT).
AUC = area under the receiver operating characteristic curve; CI = confidence interval; LR = likelihood ratio.

Supplementary Material 5: Pragmatic Diagnostic Accuracy of POCUS and XR across Anatomical Subsite (Indeterminate = Test Failure) and Sensitivity Analysis for Thoracic Inlet

Part A. Pragmatic accuracy (indeterminate results counted as test failures)

Anatomical Region	POCUS Sensitivity % (95% CI)*	POCUS Diagnostic Yield % (n/N)	XR Sensitivity % (95% CI)	XR Specificity % (95% CI)
Glottis (AP)	80.0 (68.1–88.9)†	86.5 (128/148)	26.4 (15.3–40.3)	94.7 (88.1–98.3)
Cricoid (transverse)	58.2 (46.3–69.4)	89.9 (133/148)	73.2 (61.4–83.1)	96.1 (89.0–99.2)
Cricoid (AP)	85.0 (73.4–93.0)	87.2 (129/148)	87.5 (73.2–95.8)	94.4 (88.3–97.9)
Cervical trachea at isthmus (transverse)	89.3 (80.1–95.3)	91.2 (135/148)	82.1 (69.6–91.1)	96.7 (90.8–99.3)
Cervical trachea below isthmus (transverse)	88.1 (78.2–94.6)	89.9 (133/148)	73.1 (59.0–84.4)	95.8 (89.7–98.9)

Anatomical Region	POCUS Sensitivity % (95% CI)*	POCUS Diagnostic Yield % (n/N)	XR Sensitivity % (95% CI)	XR Specificity % (95% CI)
Thoracic inlet (transverse)	0.0 (0.0–7.4)	32.4 (48/148)	66.7 (51.6–79.6)	100 (96.4–100)

**Sensitivity calculated only among patients with a diagnostic POCUS result (i.e., excluding indeterminates from denominator).*
† Glottic POCUS sensitivity in pragmatic analysis lower than per-protocol due to 20% indeterminate results.

Part B. Sensitivity analysis for indeterminate POCUS results at the thoracic inlet

Analysis	Sensitivity (95% CI)	Specificity (95% CI)
Primary analysis (indeterminate excluded)	0.0% (0.0–7.4)	100% (96.4–100)
Sensitivity analysis (indeterminate reclassified as negative)	0.0% (0.0–7.4)	100% (96.4–100)
Impact on composite diagnosis (stenosis at any site)	51.5% (41.3–61.6)	93.9% (83.1–98.7)

CI = confidence interval; POCUS = point-of-care ultrasound; XR = neck radiography.

Supplementary Material 6: Diagnostic Accuracy of Point-of-Care Ultrasound (POCUS) by Anatomical Subsite versus CT Reference Standard (n=148)

Anatomical Subsite (diameter measurement)	Sensitivity (95% CI)	Specificity (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)	AUC (95% CI)
Glottis (AP measurement)	92.5% (81.8–97.9)	83.2% (74.1–90.1)	5.49 (3.49–8.64)	0.09 (0.04–0.23)	0.878 (0.814–0.926)
Cricoid cartilage (transverse measurement)	64.8% (52.5–75.8)	90.9% (82.2–96.3)	7.13 (3.45–14.74)	0.39 (0.28–0.54)	0.778 (0.703–0.843)
Cricoid cartilage (AP measurement)	97.5% (86.8–99.9)	88.9% (81.4–94.1)	8.78 (5.14–15.00)	0.03 (0.00–0.20)	0.932 (0.879–0.967)

Anatomical Subsite (diameter measurement)	Sensitivity (95% CI)	Specificity (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)	AUC (95% CI)
Cervical trachea at isthmus (transverse measurement)	98.2% (90.4–100.0)	85.9% (77.0–92.3)	6.95 (4.20–11.52)	0.02 (0.00–0.15)	0.920 (0.864–0.959)
Cervical trachea at isthmus (AP measurement)	92.7% (82.4–98.0)	86.0% (77.3–92.3)	6.63 (3.99–11.04)	0.09 (0.03–0.22)	0.894 (0.833–0.938)
Cervical trachea below isthmus (transverse measurement)	98.1% (89.7–100.0)	89.6% (81.7–94.9)	9.42 (5.23–16.95)	0.02 (0.00–0.15)	0.938 (0.887–0.971)
Cervical trachea below isthmus (AP measurement)	7.7% (2.1–18.5)	100% (96.2–100)	—†	0.92 (0.85–1.00)	0.538 (0.455–0.621)
Thoracic trachea at inlet (transverse measurement)	0.0% (0.0–7.4)	100% (96.4–100)	—†	1.00 (1.00–1.00)	0.500 (0.417–0.583)
Thoracic trachea at inlet (AP measurement)	0.0% (0.0–9.0)	100% (96.7–100)	—†	1.00 (1.00–1.00)	0.500 (0.417–0.583)
Thoracic trachea below inlet (transverse measurement)	0.0% (0.0–17.6)	100% (97.2–100)	—†	1.00 (1.00–1.00)	0.500 (0.417–0.583)
Thoracic trachea below inlet (AP measurement)	0.0% (0.0–28.5)	100% (97.3–100)	—†	1.00 (1.00–1.00)	0.500 (0.417–0.583)

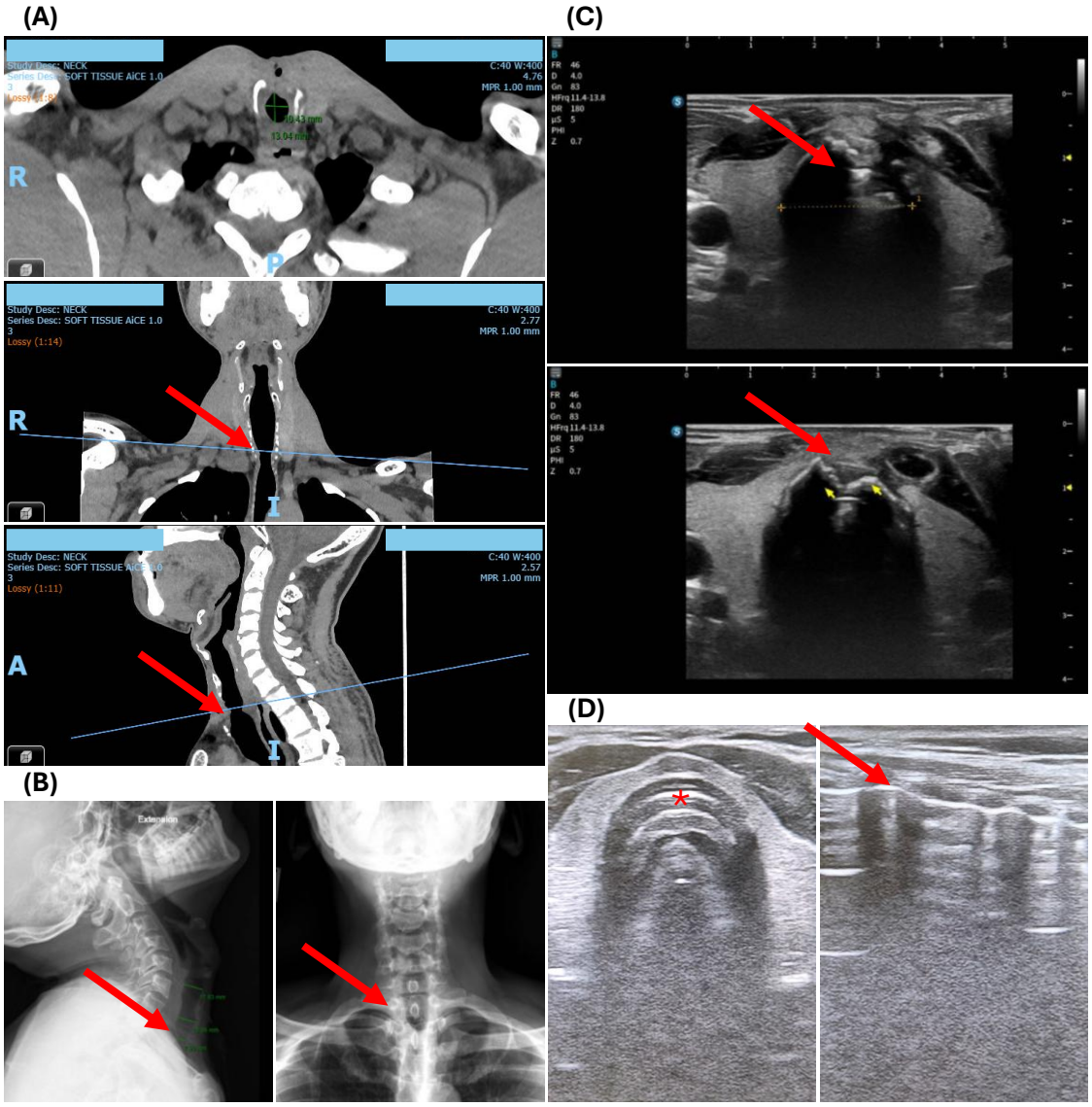
AP = anteroposterior; AUC = area under the receiver operating characteristic curve; CI = confidence interval; LR = likelihood ratio.
† LR+ cannot be calculated when sensitivity is 0%.
Note: POCUS demonstrates excellent sensitivity for accessible anterior cervical structures but is not suitable for assessing the thoracic trachea.

Supplementary Material 7: Diagnostic Accuracy of Neck Radiography (XR) by Anatomical Subsite versus CT Reference Standard (n=148)

Anatomical Subsite (View)	Sensitivity (95% CI)	Specificity (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)	AUC (95% CI)
Glottis (AP measurement)	26.4% (15.3–40.3)	94.7% (88.1–98.3)	5.02 (1.91–13.16)	0.78 (0.66–0.92)	0.606 (0.522–0.685)
Cricoid cartilage (AP measurement)	73.2% (61.4–83.1)	96.1% (89.0–99.2)	18.80 (6.14–57.51)	0.28 (0.19–0.41)	0.847 (0.778–0.901)
Cricoid cartilage (transverse measurement)	87.5% (73.2–95.8)	94.4% (88.3–97.9)	15.75 (7.17–34.58)	0.13 (0.06–0.30)	0.910 (0.852–0.951)
Cervical trachea at isthmus (AP measurement)	82.1% (69.6–91.1)	96.7% (90.8–99.3)	25.19 (8.22–77.18)	0.18 (0.11–0.32)	0.894 (0.833–0.939)
Cervical trachea at isthmus (transverse measurement)	87.3% (75.5–94.7)	98.9% (94.2–100.0)	81.16 (11.52–571.64)‡	0.13 (0.06–0.26)	0.931 (0.877–0.966)
Cervical trachea below isthmus (AP measurement)	73.1% (59.0–84.4)	95.8% (89.7–98.9)	17.54 (6.63–46.43)	0.28 (0.18–0.44)	0.845 (0.776–0.899)
Cervical trachea below isthmus (transverse measurement)	61.5% (47.0–74.7)	95.8% (89.7–98.9)	14.77 (5.53–39.48)	0.40 (0.28–0.57)	0.787 (0.712–0.850)
Thoracic trachea at inlet (AP measurement)	66.7% (51.6–79.6)	100% (96.4–100)	—‡	0.33 (0.22–0.50)	0.833 (0.763–0.889)
Thoracic trachea at inlet (transverse measurement)	48.7% (32.4–65.2)	100% (96.7–100)	—‡	0.51 (0.38–0.70)	0.744 (0.665–0.812)
Thoracic trachea below inlet (AP measurement)	47.4% (24.4–71.1)	98.5% (94.5–99.8)	30.55 (7.13–130.84)	0.54 (0.35–0.82)	0.729 (0.650–0.799)
Thoracic trachea below inlet (transverse measurement)	0.0% (0.0–28.5)	100% (97.3–100)	—†	1.00 (1.00–1.00)	0.500 (0.417–0.583)

AP = anteroposterior; AUC = area under the receiver operating characteristic curve; CI = confidence interval; LR = likelihood ratio.
† LR+ cannot be calculated when sensitivity is 0%.
‡ LR+ approaches infinity when specificity is 100%; 95% CI cannot be calculated.

Note: Neck XR provides moderate sensitivity and very high specificity across most anatomical levels, but performs poorly for glottic assessment.



Supplementary Material 8: Comparative Imaging of Laryngotracheal Stenosis (LTS) and Normal Airway Anatomy

Panel A – MDCT with multiplanar reformation (MPR)
Patient with caudal cervical tracheal stenosis at the level of a previous tracheostoma. From top to bottom: axial, coronal, and parasagittal planes demonstrate focal luminal narrowing (arrows).

Panel B – Corresponding soft-tissue neck radiographs
Same patient. Lateral and anteroposterior (AP) views show focal narrowing of the air column (arrows).

Panel C – Point-of-care ultrasound (POCUS) of the stenosis
Same patient, imaged at the level of the stenosis, caudal to the thyroid isthmus. Images reveal loss of the normal air-mucosa interface and luminal narrowing (arrows).

Panel D – Normal airway for comparison
POCUS images at the level of the thyroid isthmus show a normal tracheal lumen. Transverse view (left) demonstrates the characteristic reverberation artifact (asterisk) deep to the anterior wall. Longitudinal view (right) reveals the typical appearance of the cricoid cartilage and subsequent tracheal rings, with posterior acoustic shadowing (arrow).

Source: *All images were obtained from patients enrolled in the study during the period 2023–2025 at Frere Hospital, Eastern Cape, South Africa. Panels A–C: Patient with CT-confirmed LTS (≥50% narrowing). Panel D: Representative normal airway from a study participant without stenosis. Images are original and were acquired, interpreted, and anonymised by the authors.*

Acquisition details:

- ***MDCT:*** *320-row Aquilion ONE; 0.5 mm collimation; 100–120 kVp; multiplanar reformations at 0.5–1.0 mm slice thickness.*
- ***Radiography:*** *Standard upright AP and lateral soft-tissue neck X-rays during full inspiration with neck extension.*
- ***POCUS:*** *Butterfly iQ+ handheld ultrasound with linear transducer (5–10 MHz); quiet respiration; transverse and longitudinal planes.*