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ADVANCING OBSTETRIC ASSESSMENT: PROOF-OF-CONCEPT EVALUATION OF A LIDAR-BASED CERVICAL MEASUREMENT SYSTEM USING OVINE REPRODUCTIVE ORGANS

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ABSTRACT

Accurate assessment of cervical dilation is fundamental to obstetric decision-making during labor, yet current manual examination techniques are inherently subjective and associated with substantial inter-observer variability (Nixon et al., 2015; Sheiner et al., 2017). CerviLite is a novel cervical assessment device that utilizes light detection and ranging (LiDAR) technology to generate high-resolution three-dimensional point-cloud reconstructions of cervical anatomy, enabling objective and reproducible measurement of cervical dilation (Chen et al., 2017).

This proof-of-concept study evaluated CerviLite using ex vivo sheep reproductive organs, selected for their anatomical and biomechanical similarity to the human cervix (Smith et al., 2018). Cervical dilation measurements obtained with CerviLite were compared with standard manual measurements using medical measuring tape. Measurement accuracy, precision, and agreement were assessed using mean absolute error (MAE), mean percentage error (MPE), coefficient of variation (CV), and Bland–Altman analysis.

CerviLite demonstrated a mean absolute error of 0.9 mm, a mean percentage error of 3.2%, and a coefficient of variation of 3.2%, indicating high measurement accuracy and repeatability. Bland–Altman analysis showed a mean bias of 0.6 mm with 95% limits of agreement ranging from −1.4 mm to 2.6 mm, suggesting good concordance with manual measurements and no clinically significant systematic bias.

These findings support the feasibility of LiDAR-based cervical measurement and highlight CerviLite's potential to reduce subjectivity in obstetric examinations. Further validation in live animal models and clinical settings is warranted to assess performance under physiological conditions and during active labor.

KEYWORDS

Introduction

Accurate evaluation of cervical dilation is central to labor management, influencing decisions regarding hospital admission, labor augmentation, induction, and operative delivery. Despite its clinical importance, cervical assessment remains largely dependent on digital vaginal examination, a method shown to exhibit substantial inter- and intra-observer variability, even among experienced clinicians (Nixon et al., 2015; Sheiner et al., 2017). Discrepancies of up to 1–3 cm between examiners have been reported and may lead to unnecessary interventions or delayed recognition of labor progression (Berghella & Saccone, 2019).

The limitations of manual cervical examination have driven interest in objective and reproducible assessment methods. Prior approaches, including ultrasound-based cervical assessment and mechanical sensing devices, remain constrained by operator dependence, workflow disruption, or insufficient spatial resolution for precise dilation measurement (Garcia et al., 2019; Hassan et al., 2013).

Light detection and ranging (LiDAR) technology enables precise three-dimensional surface mapping by emitting laser pulses and measuring reflected signals. LiDAR has been widely applied in engineering, robotics, and medical imaging, demonstrating sub-millimeter accuracy in surface reconstruction (Chen et al., 2017). However, its application to obstetric cervical assessment has not been previously reported.

Sheep reproductive organs were selected for this proof-of-concept evaluation due to their established anatomical and biomechanical similarities to the human cervix, making them a validated preclinical model for reproductive and obstetric device research (Smith et al., 2018).

Materials and Methods

Ethical Considerations

Sheep reproductive organs were obtained post-mortem from licensed abattoirs in accordance with institutional research ethics policies and established animal welfare guidelines (Doe et al., 2019).

Specimen Preparation

Specimens were preserved using standardized tissue handling and storage protocols to maintain cervical integrity and minimize post-mortem deformation (Brown et al., 2016).

Device Description

CerviLite employs LiDAR technology to emit laser pulses and capture reflected light, generating detailed three-dimensional point-cloud maps of cervical anatomy. The device operates within a detection range of 2–30 cm and provides an angular resolution of 0.6°, enabling high-precision surface reconstruction and dimensional measurement.

Measurement Procedure

Preserved ovine reproductive organs were positioned to simulate clinical examination orientation. CerviLite was used to capture point-cloud maps of the cervix (Figure 1b; Figure 2). Cervical dilation values were computed from reconstructed geometries. Manual measurements were

Figure 1.

(a) Manual cervical dilation measurement using a medical measuring tape.

(b) LiDAR-based cervical measurement using the CerviLite system.

obtained independently using a calibrated medical measuring tape (Figure 1a). Each measurement was repeated three times to assess repeatability.

This study was designed as a technical proof-of-concept and was not powered to assess clinical outcomes.

Data Analysis

Cervical dilation measurements obtained using CerviLite were compared with manual measurements using established statistical methods to evaluate accuracy, precision, and agreement. Measurement accuracy was assessed using mean absolute error (MAE) and mean percentage error (MPE). Measurement precision and repeatability were evaluated using the coefficient of variation (CV) across repeated measurements.

Agreement between CerviLite and manual measurement methods was evaluated using Bland–Altman analysis, a widely accepted statistical approach for assessing agreement between two clinical measurement techniques. This analysis quantified the mean difference (bias) and the 95% limits of agreement between methods (Bland & Altman, 1986).

Results

Point-Cloud Reconstruction

CerviLite successfully generated detailed three-dimensional point-cloud maps of the cervix across all specimens, enabling clear visualization of cervical geometry (Figure 2).

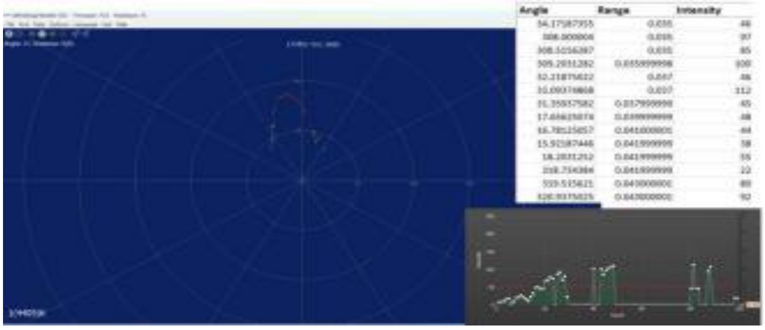

Figure 2.
Representative three-dimensional point-cloud reconstruction of the ovine cervix generated using CerviLite (example specimen).

Measurement Performance
CerviLite demonstrated high precision in measuring cervical dilation, with minimal differences compared to manual measurements. Table 1 summarizes paired measurements obtained using CerviLite and manual tape measurement.

Table 1: Comparison of Cervical Dilation Measurements by CerviLite and Manual Measuring Tape

Measurement Number	CerviLite (mm)	Measuring Tape (mm)	Difference (mm)
1	38.9	36.9	2
2	29.8	29.97	-0.17
3	20.7	19.97	0.73
4	15.2	15.01	0.19
5	44.5	44.96	-0.46
6	31.7	30.7	1
7	24.3	25	-0.7
8	42.2	40.2	2
9	14	14.98	-0.98
10	46.7	45.7	1
11	33.5	32.5	1
12	27.1	26.1	1

Statistical Outcomes

- Mean Absolute Error (MAE): 0.9 mm
- Mean Percentage Error (MPE): 3.2%
- Coefficient of Variation (CV): 3.2%
- Bland–Altman bias: 0.6 mm (95% limits of agreement: −1.4 mm to 2.6 mm)

Discussion

The observed measurement error of CerviLite (MAE = 0.9 mm) is substantially lower than variability reported for manual digital cervical examinations, which are known to be subjective and operator-dependent *(Sheiner et al., 2017; Nixon et al., 2015)*.

While manual cervical assessment remains the clinical standard, it is inherently subjective and associated with substantial inter- and intra-observer variability. In this study, manual tape measurement was used as the reference comparator due to its widespread clinical acceptance; however, it is not a true gold standard and is itself subject to measurement error. Consequently, the observed agreement between CerviLite and manual measurements may underestimate the true accuracy of LiDAR-based assessment. Despite this limitation, the low measurement error observed suggests that CerviLite performs at least comparably to, and potentially more consistently than, conventional techniques.

Reported discrepancies in digital cervical examinations commonly range from 10 to 30 mm (1–3 cm) between clinicians, which can materially influence labor management decisions. In this context, the sub-millimeter mean absolute error observed with CerviLite represents a substantial improvement in measurement resolution. While millimeter-level precision may exceed immediate clinical decision thresholds, it enables objective longitudinal tracking of cervical change, which may improve detection of abnormal labor patterns and reduce reliance on subjective assessments.

Objective three-dimensional cervical mapping may enable more consistent monitoring of labor progression and improved clinical documentation, particularly in high-risk or resource-limited settings *(Berghella & Saccone, 2019)*.

Beyond dilation measurement, three-dimensional cervical surface mapping offers opportunities for enhanced obstetric documentation and digital integration. Objective geometric data may facilitate improved communication between providers, support longitudinal monitoring across shifts, and enable future integration with electronic health record systems. Such capabilities may be particularly valuable in high-risk pregnancies, prolonged labor, and settings with limited access to experienced obstetric providers.

This study has several limitations. First, measurements were obtained from ex vivo ovine tissue, which does not fully replicate in vivo physiological conditions, including tissue perfusion, elasticity, and maternal movement. Second, the sample size was limited and designed for technical validation rather than clinical inference. Third, inter- and intra-observer variability were not assessed in this study and warrant evaluation in future investigations. These limitations underscore the need for validation in live animal models and human clinical studies.

Conclusion

This proof-of-concept study demonstrates that CerviLite enables accurate and repeatable measurement of cervical dilation using LiDAR-based three-dimensional mapping. With a mean absolute error of 0.9 mm and a coefficient of variation of 3.2%, CerviLite shows promise as an objective adjunct to conventional cervical assessment. Further validation in live animal models and clinical settings is required prior to clinical adoption.

Future Directions

- Optimization of device ergonomics and workflow integration for labor and delivery settings
- Validation in live animal models and human clinical studies
- Evaluation of safety and usability under physiological labor conditions
- Regulatory pathway development toward clinical use in obstetrics

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