Quantifying the effect of slice thickness on the imaging performance of ultrasound scanners

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INTRODUCTION AND BACKGROUND

- The **Edinburgh Pipe Phantom (EPP)** is used to measure the **resolution integral (R)** which is a figure of merit that characterises the ratio of penetration to spatial resolution of ultrasound scanners & transducers.
- We have previously demonstrated that the EPP can measure the performance of diagnostic & pre-clinical ultrasound probes between 2.5-55MHz, and quantify changes in performance due to faults, application of 2D image enhancement and control setting optimisation[1].

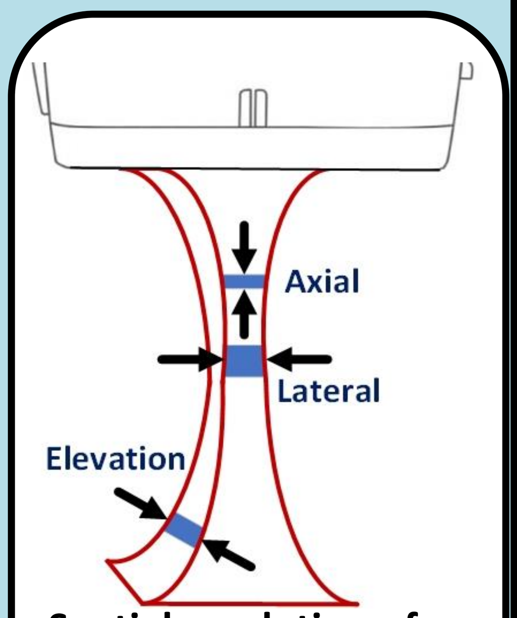
Resolution Integral (R)

Dimensionless figure of merit (*R*) for **performance assessment** of medical ultrasound probes; accompanied by **characteristic resolution D_R and depth of field L_R** where L_R is defined as the region of best imaging and D_R is the typical lateral resolution within the depth of field.

$$R = \int_0^\infty L \, d\alpha$$

Where *L* is the depth range over which an object of diameter 1/α can be resolved

- We have demonstrated the effects of slice thickness on *curvilinear, linear and multi-row arrays (1.25D)* and shown that by removing the effect of slice thickness we can increase R and decrease D_R values by factors greater than 2.5 and 3 respectively[2].

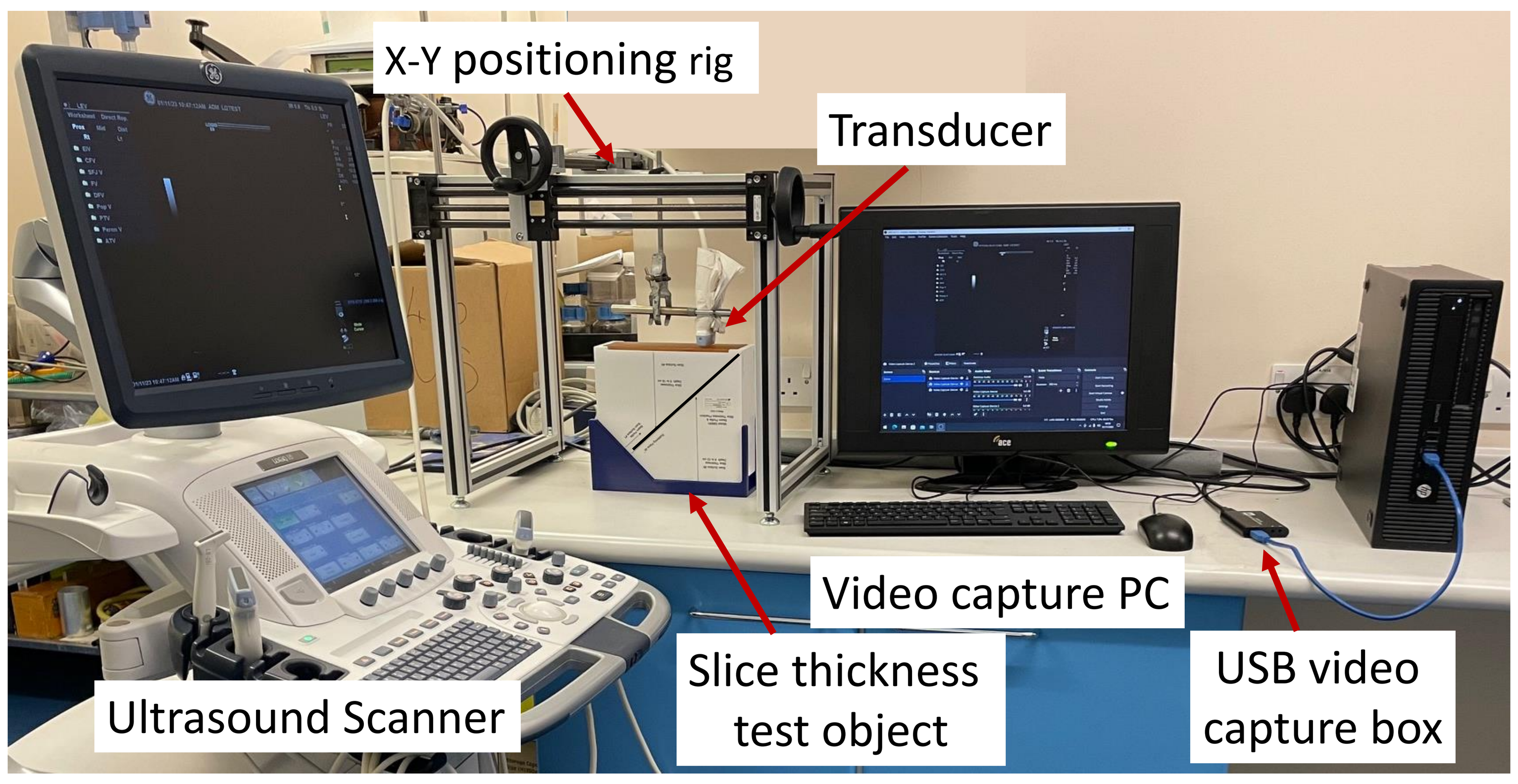


Spatial resolution of an ultrasound transducer

AIM

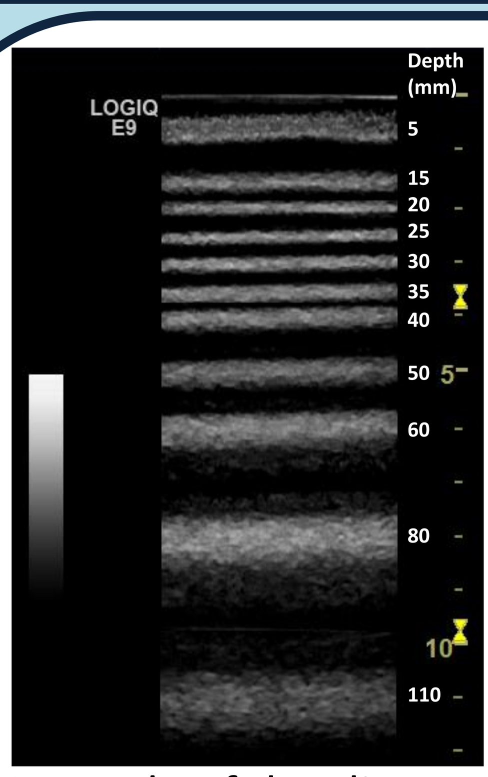
Develop a method for calculating R only in the slice thickness (ST) dimension (R(ST)) and compare results with R measured using the EPP (R(EPP)).

MEHODS

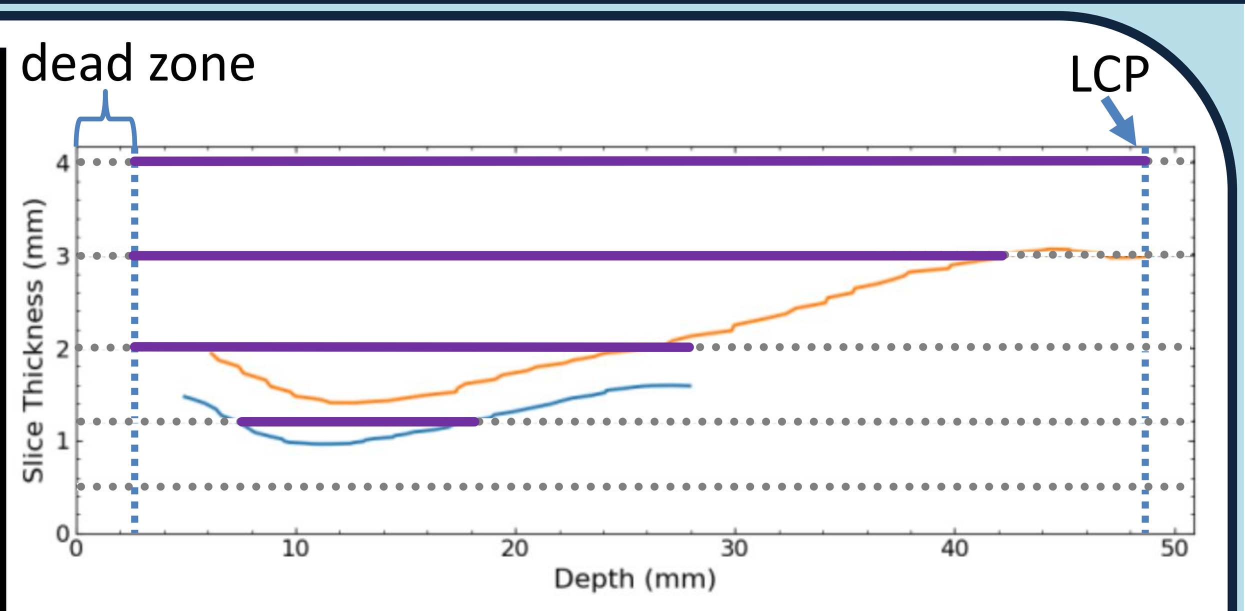


- The experimental setup, shown above, was used to acquire video clips of slice thickness of an ultrasound transducer.
- A CIRS ATS 538NH test object was used to visualise the slice thickness from 3x curvilinear, 2x linear and 3x multi-row linear array transducer models.
- During the video capture, the probe was moved at a constant speed over both surfaces of the test object and aqueous gel was used as the coupling agent.
- Videos were processed using custom software developed to reconstruct the slice thickness beam profiles and calculate R (ST), L_R(ST) and D_R (ST) values.

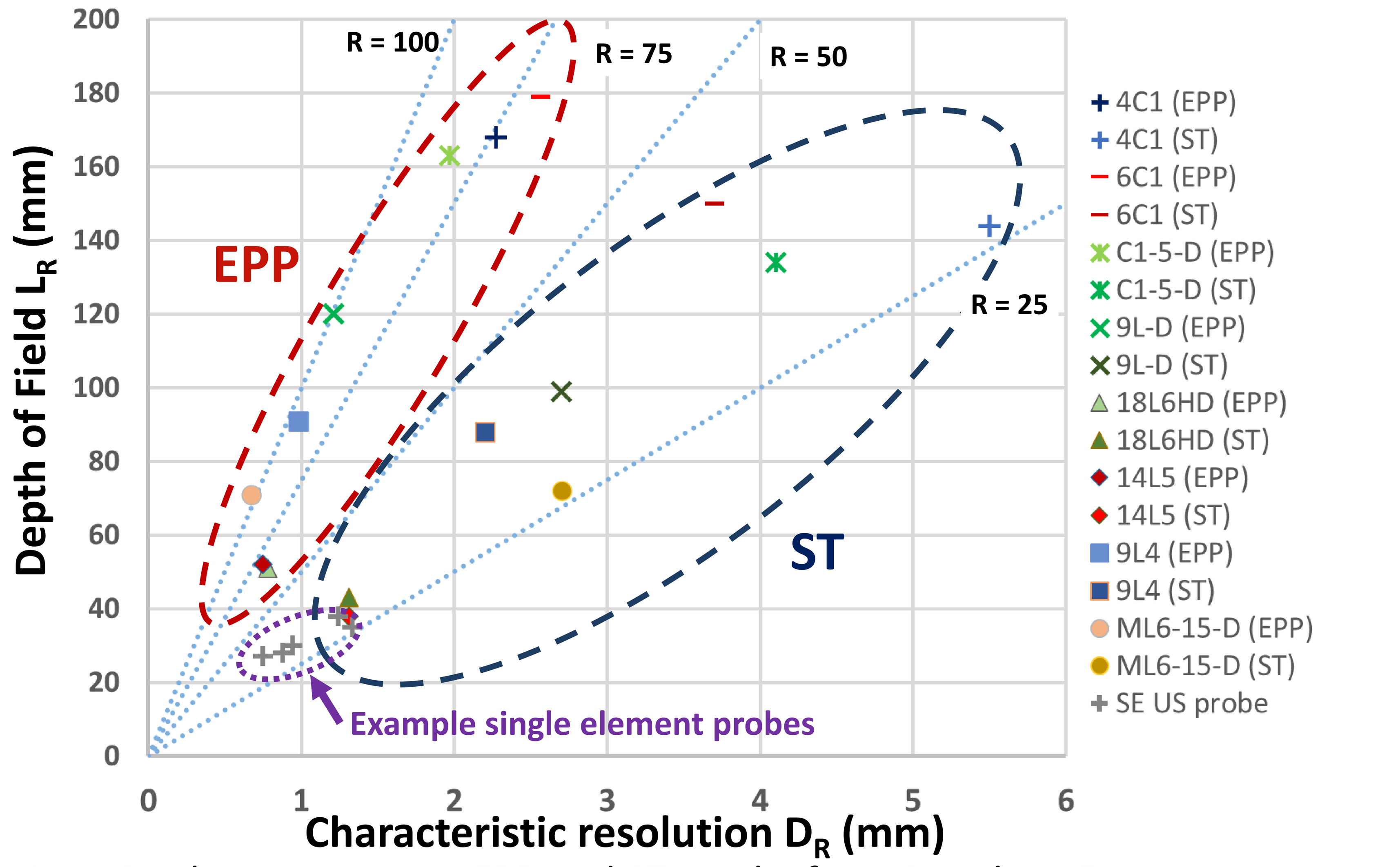
RESULTS



Example of the slice thickness captured at multiple depths using a 9L-D linear transducer



Example of slice thickness depth profiles with shallow (blue) and deep (orange)settings extracted from videos and processed. The dotted horizontal lines indicate theoretical pipe diameters & solid purple horizontal lines denote the calculated length L.



L_R vs D_R chart comparing EPP and ST results from 8 probes. For comparison L_R(EPP) and D_R(EPP) values of 5 single element (SE) probes are included.

From the 8 transducer models & types tested:

- R(ST) & D_R(ST) were on average 2.6 ± 0.65 times smaller (mean ± standard deviation) and 2.24 ± 0.8 times larger than R(EPP) & D_R(EPP) respectively.
- L_R(ST) was on average 1.17 ± 0.12 times smaller than L_R(EPP).

DISCUSSION

- This technique, incorporating an ATS 538NH test object, allowed us to assess the performance of elevation focusing.
- Transducers tested were from a limited pool of models and types, using only 1D or 1.25D elevation focusing techniques.
- Highlights the need to expand the assessment of slice thickness using a wider pool of transducers, including 1.5D, 1.75D and 2D arrays, to further investigate the relationship of R(EPP) and R(ST).
- Highlights the need for clinical adoption of improved transducer designs to achieve better elevational focusing.

CONCLUSION

- **Slice thickness is an important limiting factor in the imaging performance of ultrasound transducers.**
- **Our proposed method allowed us to quantify slice thickness of a transducer.**
- **The performances of the clinical transducers tested, including three modern multi-row transducers, were comparable to single element transducers in the elevation plane.**

References

[1]Moran CM et al. The Imaging Performance of Diagnostic Ultrasound Scanners Using the Edinburgh Pipe Phantom to Measure the Resolution Integral – 15 Years Experience. Ultraschall in der Medizin 2022;43:393-402

[2]Carstairs H. et al. A novel ultrasound phantom to quantify the effect of slice thickness on imaging performance. 2019 IEEE Ultrasonics Symposium 2404-2407.

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