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Experiment demonstrating that ultrasound contrast microbubbles require specialised low MI software

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1 Introduction

The Mechanical Index (MI)

The Mechanical Index (MI) is defined as the peak negative sound pressure divided by the square root of the transmitted frequency. It is a standard measure of ultrasound energy and is closely linked to the likelihood of cavitation (Gibbs, Cole and Sassano, 2009). Contrast agents containing gas microbubbles increase cavitation sensitivity, meaning bubble oscillation becomes more pronounced under ultrasound. MI values above 0.3 can cause microbubble destruction, whereas lower MI values (<0.3) support stable contrast enhancement (Solbiati et al., 2006).

SonoVue Microbubbles as an Ultrasound Contrast Agent

SonoVue is a contrast agent composed of sulphur hexafluoride gas encapsulated in a phospholipid shell (Senior et al., 2017). Microbubbles enhance ultrasound images through non-linear scattering and allow real-time assessment of tissue perfusion. Unlike CT or MRI contrast agents, microbubbles are eliminated rapidly through the lungs, making them suitable for patients with renal impairment (Cosgrove & Eckersley, 2006). Optimal imaging requires low-MI settings to avoid premature bubble destruction and to maintain diagnostic clarity. The Canon Aplio i800 system includes contrast-specific software to support microbubble visualization, although some advanced features (e.g., bubble tracing) cannot be demonstrated in a simple tube phantom.

Aim of the Study

This study aims to demonstrate that increasing the MI—either through the high-MI "Flash" function or by switching to a standard abdominal preset—results in rapid microbubble destruction within the phantom model.

Image 1.: A Flash is a brief, high-energy ultrasound pulse that intentionally raises the Mechanical Index to destroy microbubbles within the imaging field. On Canon systems, it is used to clear contrast from a region so that subsequent replenishment of microbubbles can be observed (Hanlon, 2025).

Image 2.: The **lumen of the tube** was measured using **B-mode imaging.**

2 Methods

Ultrasound Probe:
A 3–5 MHz curvilinear abdominal probe was used to generate pressure changes matched to the microbubble resonant frequency.

Image 3.: equipment set up

Phantom Setup:
A RUSCH PTFE Aqua Flate Foley catheter (Ch. 16.5, 3/10 ml) was embedded in a gelatine phantom (20 g gelatin in 2000 ml warm water) to simulate tissue.

Ultrasound System:
The Canon Aplio i800 was operated in **Contrast Harmonic Imaging (CHI)** mode with split-screen display:
low-MI fundamental imaging (orientation) and
sepia contrast harmonic imaging (microbubble visualisation).

Data Collection:
Microbubbles were destroyed using the **Flash** (high-MI) pulse, activated via the Flash button or by switching from CHI to a standard abdominal preset.

Contrast Agent:
SonoVue (Bracco) was drawn into a saline-filled syringe and administered to generate microbubbles.

Figures 4–6: Bracco SonoVue Setup

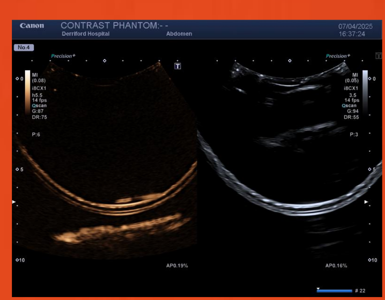
Data Analysis:
The catheter lumen was assessed for remaining microbubbles. Additional Flash pulses were applied if bubbles persisted. Outcomes were recorded as cine loops and static images.

Recording:
Images and cine loops were saved to a USB drive and later combined with voice-over narration in PowerPoint before upload to YouTube.
Please click on the following link to watch the video:
https://youtu.be/QfvEzyfguzc?si=KrP6YNzTd9In4LuS

3 Results

Image 5. : CHI Activation: The **CHI (Contrast Harmonic Imaging) button** on the Canon ultrasound console is pressed to initiate contrast imaging, enabling low-MI harmonic visualization of microbubbles.

Image 6.: Contrast Harmonic Imaging (CHI) ready for injection: Right: Fundamental B-mode image **Left:** Sepia contrast harmonic image for enhanced contrast observation
(Hanlon, 2025)



1 mL of SonoVue was drawn into a 10 mL pre-filled 0.9% saline flush syringe and injected through the Foley catheter. Cine loops and static images were recorded (see 1:36 in the video). The microbubbles were then exposed to a high-MI 'Flash' pulse (MI 1.47), resulting in their destruction.

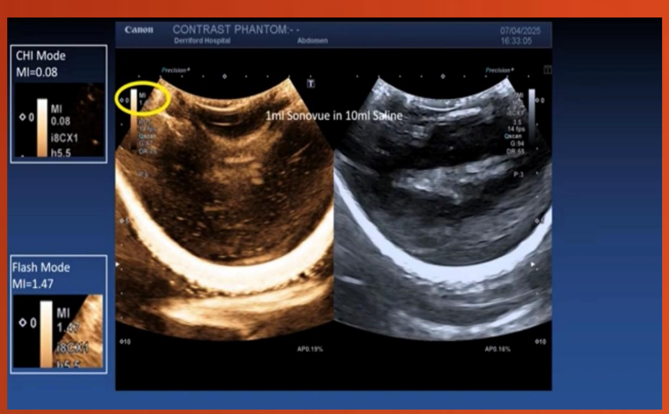


Image 7.: Activating the Flash function increased the Mechanical Index from 0.08 to 1.47 on the sepia contrast image (left panel).

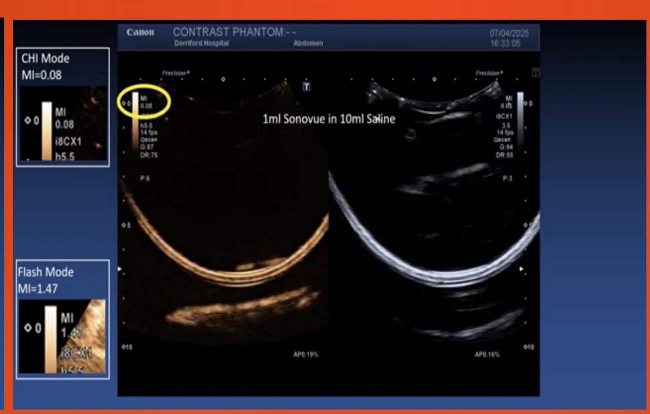


Image 8.: Activating the Flash button resulted in complete microbubble destruction within the lumen of the Foley catheter.

0.1 mL of SonoVue was mixed with 50 mL of saline. A 3-second high-MI Flash pulse (MI 1.47) was applied to ensure complete microbubble destruction. Following Flash activation, the catheter lumen was cleared of bubbles (see 2:38 in the video).

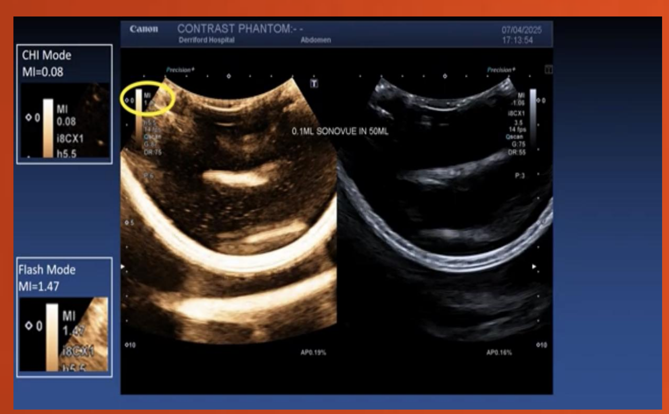


Image 9.: Scan demonstrating the presence of microbubbles prior to Flash activation.

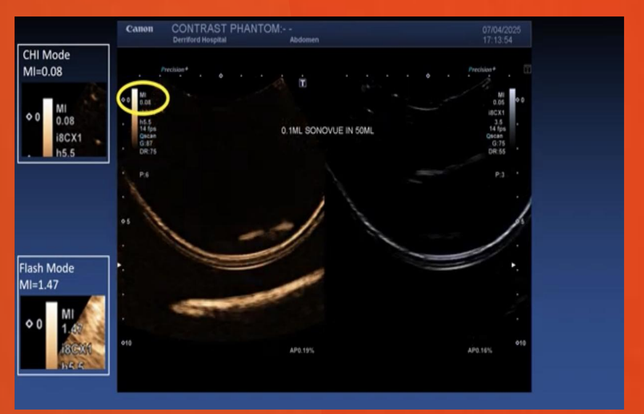


Image 10.: After Flash activation with an MI of 1.47, the catheter lumen is completely free of microbubbles.

Switching from the CHI preset to the Standard Abdominal preset increased the MI from 0.08 to 1.2, resulting in microbubble destruction, which was recorded.

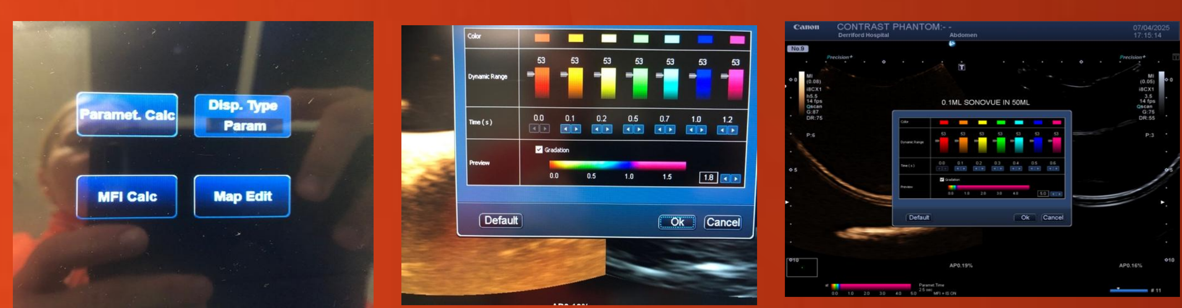
Image 11.: CHI preset displayed before switching to the Standard Abdominal preset.

Image 12.: Using a mechanical index (MI) of 1.2 with the standard abdominal preset resulted in destruction of microbubble contrast agents.

Other aspects of the Canon low MI software that could not be testes using a gelatine phantom

Multiparametric imaging

Colour-coded parametric mapping displays microbubble arrival time from red (early arrival) to blue (late arrival) as the bubbles move from right to left across the imaging field. The timing interval was set to 0.1 seconds to capture the rapid transit of the bubbles. A video recording was obtained to demonstrate the progression of the colour-coded microbubbles.



Images 13-15.: Parametric Calc: Parametric Microflow Imaging (Hanlon, 2025)
Colour-coded parametric mapping visualises microbubble flow and arrival time, providing a temporal map of contrast movement within the imaging field.

Image 16: Arrival is mapped from early to late to visualise microbubble transit.

Image 17.: 2.5 cm haemangioma showing centripetal filling.
Colour is allocated according to the time between contrast arrival and full enhancement (Hodgson, 2025).

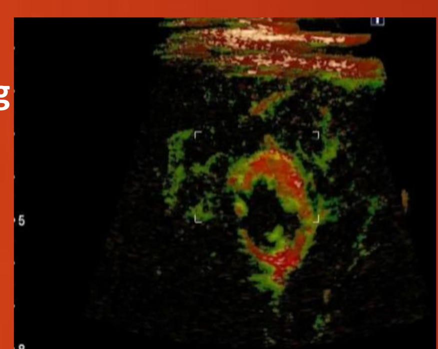
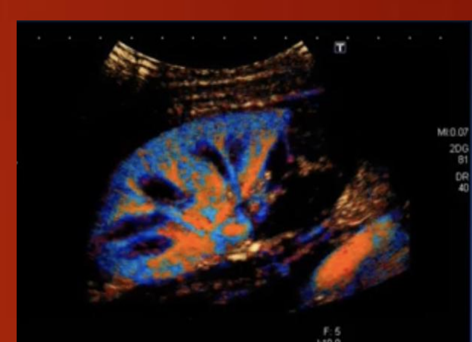


Image 18.: Multiparametric imaging seen on a renal transplant (Hogdson, 2025)

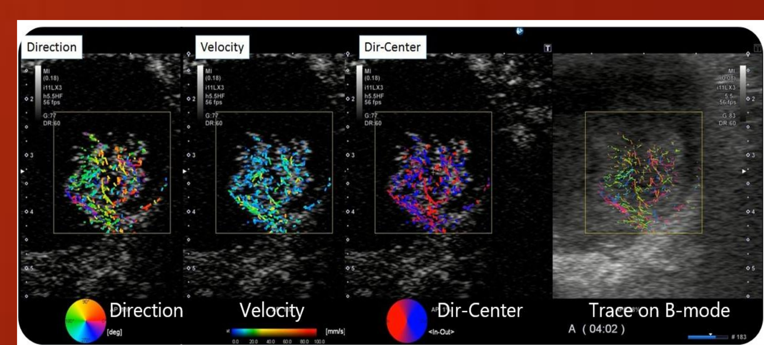


VRI – Vascular Recognition Imaging

Image 19-20.: VRI colour codes according to the direction of moving bubbles and static bubbles are demonstrated in the colour green.
Saline is infused and stopped intermittently demonstrating moving bubbles in colour and static bubbes in green.

Vector Imaging (bubbles tracking)

Image 21.: Gallbladder lesion images courtesy of Canon Medical Systems. VRI allowing to identify the bubble flow direction in colour. Individual contrast bubbles can be traced to visualise fine vascular structure inside lesions (note high frame rate allows the superb spatial and temporal resolution needed for this feature)" (Hodgson, 2025).



4 Discussion

The phantom study successfully demonstrated that a high Mechanical Index (MI) destroys microbubbles, and together with the recorded video, it can serve as an effective educational tool. A high MI can be achieved either by using the "flash" mode within the contrast software or by selecting a standard non-contrast abdominal preset. This experiment confirmed that combining second-generation ultrasound contrast agents with dedicated low-MI microbubble imaging techniques enables accurate assessment of dynamic flow enhancement.
The phantom was also useful in illustrating that contrast-specific imaging software is required to exploit the non-linear behaviour of microbubbles and achieve clinically meaningful signal enhancement. Furthermore, it demonstrated that when the MI is increased to 1.47, bubble destruction occurs rapidly—within only a few flash activations—depending on bubble concentration.

5 Conclusion

It is important to maintain a low Mechanical Index (MI) during contrast-enhanced ultrasound (CEUS) to prevent microbubble destruction and avoid the need for repeat scans. Awareness of MI settings is essential for ensuring both image quality and patient safety, especially as the "off-label" use of SonoVue becomes more common. The experiment could also be repeated using contrast agents from different manufacturers to assess potential variations and evaluate how factors such as gain and frequency influence MI and image quality.

References:
1. Bagley, J.E., Paul, D.E., Halferty, S. and Digiacinto, D. (2018) The Use of Contrast-enhanced Ultrasonography for the Characterisation of Focal Liver Lesions. *Sonography* [online]. 5, pp. 120-134. [Accessed 30 March 2025]. 2. Cosgrove, D., Eckersley R. (2006) Contrast Enhanced Ultrasound: Basic Physics and Technology Overview. In Lencioni, R., ed. (2006) Enhancing the Role of Ultrasound with Contrast Agents [online]. Springer, pp. 3-4. [Accessed 22.4.2025]. 3. Dietrich, C.F., Dong, Y., Nolsoe, C.P., Barr, R.G., Berzigotti, A., Burns, P.N., Cantisani, V., Chammas, M.C., Chaubal, N., Choi, B.I., Clevert, D.-A., Cui, X., D'onofrio, M., Fawlkes, J.B., Gilja, O.H., Huang, P., Ignee, A., Jenssen, C.H., Kono, Y., Kudo, M., Lassau, N., Lee, W.J., Lee, J.Y., Liang, P., Lim, A., Lyshchik, A., Meloni, M.F., Correas, J.M., Minami, Y., Moriyasu, F., Nicolau, C., Piscaglia, F., Softoin, A., Sidhu, P.S., Sporea, I., Torzilli, G., Xiex, and Zheng, R. (2020) Guidelines and Good Clinical Practice Recommendations For Contrast-enhanced Ultrasound (Ceus) in the Liver–update 2020 Wfumb in Cooperation with Efsumb, Afsumb, Aium, and Flaus. *Ultrasound in Medicine and Biology* [online]. 46 (10), pp. 2579-2604. [Accessed 20 April 2025]. 4. Gibbs, V., Cole, D. and Sassano, A. (2009) *Ultrasound Physics and Technology How, Why and When*. 10 November 2023rd ed. Cpi Anthony Rowe Eastbourne, UK: Churchill Livingstone Elsevier. 5. Hanlon, S. (2025) Contrast Enhanced Ultrasound Imaging and Canon Medical Systsmes Imaging private conversation, Derriford Hospital Plymouth NHS Trust X-Ray East, Storage room, 4th April 2025. 5. Hodgson, T. (2025) Canon Medical Systems, CHI (Contrast Harmonic Imaging) Parametric Microflow Imaging [online]. [Accessed 24 April 2025]. 6. Lim, A.K.P. and Rosselli, M. (2024) *Liver Ultrasound*. 1st pp.: 15-17th ed. Singapore: John Wiley & Sons Ltd. 7. National Institute of Clinical Excellence, NICE (2024), SonoVue (Sulphur hexafluoride microbubbles) – contrast agent for contrast – enhanced ultrasound imaging of the live (DG5) p.38. [online] [Accessed: 03 June 2025]. 8. Senior, R., Becher, H., Monaghan, M., Zamorano, J., Vanoverschelde, J.L., Nihoyannopoulos, P., Edvardsen, T., Lancellotti, P. (2017) Clinical Practice of Contrast Echocardiography: Recommendation by the European Association of Cardiovascular Imaging (EACVI). *European Heart Journal - Cardiovascular Imaging* [online]. 18 (1205) [Accessed 22 April 2025]. 9. Solbiati, L., (2024) Monitoring of Locoregional and Systemic Treatment of Cancer: the evolving role of CEUS: Bubble Power Imaging and Beyond conference. Bracco Switzerland. 6th November 2024 Plan-les-Ouates (Geneva). Bracco Switzerland.

Watch the video of this experiment online by scanning this code