

# Flip side of ultrasound—Is it absolutely safe?

## Authors:

**Hally T,** (ORCID ID : 0000-0002-7147-5674) 1-Consultant, KIMS Health care, Anayara PO, Trivandrum

**Rachel Cherian Koshy,** (ORCID ID : 0000-0002-2671-2474) Professor, Dept of anaesthesiology, SUTAMS Vattappara, Trivandrum, Kerala, India

Submitted: 05 Sep 2026

Revised: 14 Sep 2026

Accepted: 20 Sep 2026

Published: 30 Sep 2026

## Corresponding Author:

Contact: Dr Hally T., Email id :hallysharon@gmail. com

**How to cite this article:** Hally T, Rachel Cherian Koshy. Flip side of ultrasound—Is it absolutely safe. TAISAK 2026; 2(2): 22-29

Access This Article Online



Website:  
theanaesthesiologist.com

## ABSTRACT

**BACKGROUND AND AIMS:** Ultrasound scans are increasingly used in Anaesthesia practice for different purposes like central venous access, peripheral nerve blocks, truncal plane blocks, airway assessment and confirmation of endotracheal intubation in obese patients and so on. Although usage of ultrasound seems to be benign and very safe, it has some potential complication which we should be aware of. The aim of this descriptive review is to make readers aware of the complications of ultrasound usage and measures to prevent them to a certain extent. The users of ultrasound should look in to the safe limits of thermal index to minimise the thermal harm.

**Keywords:** Hazards, Ultrasound, Biological effects, Thermal effects, Teratogenic effects of heat, Cavitation and gas body effects, Thermal index

## Introduction

The ability to see inside the body non invasively is a great thing that makes the ultrasound scan as an attractive diagnostic tool among all clinicians including Anaesthesiologist. Of late ultrasound scans are increasingly being used in Anaesthesia practice. ultrasound scan is used both for diagnostic as well as for procedural purposes. central line insertion ,difficult arterial line insertion peripheral nerve block, truncal plane blocks etc are usually done under ultrasound guidance. people are using ultrasound scans for even confirmation of endotracheal intubation. The usage of ultrasound seems to be very safe it is having some potential

hazards which we should be aware of for the safe and effective use of ultrasound. Anaesthesiologist must be familiar with the out put display standards (ODS) and their safe range .The two commonly used ODS are thermal index(TI) ,which is the indicator of potential thermal harm produced by the ultrasound and mechanical index(MI)which is the indicator of potential mechanical effects .the following write up will make the readers aware of these things which is necessary for safe and effective use of ultrasound.

## HISTORY OF ULTRASOUND IN VIEW OF ITS HAZARDS

The first ultrasound transducer was used by French government to detect German submarines. The transducer was made by Werlein, a Paris optician by 16mm thick slice of quartz operating at about 150kHz. It was so powerful that it could even kill a fish by its gas body cavitation effect, which can cause rupture of the swim bladder of the fish. R.W Wood recorded later that if hand was held in the water near the transducer "an almost insupportable pain was felt." (2) They also observed incipient cavitation in water when the probe is active. In 1970 exposure from diagnostic ultrasound showed increase in human lymphocytic sister chromatic exchange (3)

## HAZARDS OF ULTRA SOUNDS

The hazards associated with ultrasounds are now well understood such as exposure to ultrasound causes tissue heating. The presence of gas in the tissues causes mechanical effects which are specific to each tissue. In body fluids or liquids ultrasounds produce aquatic cavitation. The radiation pressure causes forces on the propagating medium termed as radiation pressure effects. Each hazard is described separately in the following headings. The thermal and non thermal effects are inter related as tissue heating may facilitate non thermal effects by reducing the threshold for cavitation and cavitation in turn causes localised tissue heating.

## HAZARDS OF ULTRA SOUNDS

The energy is lost from the ultrasonic wave as it passes through the tissues as a result of viscoelastic absorption. The energy lost from the tissues depends on the amplitude and absorption coefficient of the tissues, which is variable from tissue to tissue. Ossified bone has highest absorption coefficient and lowest being the body fluids, soft tissues having the intermediate values. For soft tissue absorption coefficient is assumed to be 0.1 nepers/cm/MHz assuming no energy is deposited in the body fluids. (4). At an air interface all energy is reflected

potentially doubling the energy in tissues at interface. (5) A small bubble like inclusion in the tissue can increase significantly the energy deposition as a result of multiple scattering (6). Most of the acoustic energy deposited is converted to heat, raising the tissue temperature and cause thermal hazards. The rate of temperature rise initially will be  $2\alpha I/c$ , where  $I$  is intensity of the wave and  $c$  is the specific heat capacity of the medium. (7) Heating depends on the overall volume being heated and width of the ultrasonic beam. Broader the beam the heat generation will be more with a given peak intensity (1). Other factors affecting steady state temperature are thermal conductivity of the tissue and perfusion to the tissue.

An effective thermal conductivity is dependent upon the convective heat loss due to blood flow. Temperature rise in bone has been estimated by assuming that 50% of the power incident on the bone surface is absorbed within a thin surface layer (8.) The temperature rise of soft tissue are much slower than that of bones. Soft tissue takes several minutes to attain temperature the bone attains it with in a few seconds. (9)

## Thermal index (TI)

It is an indicator of heating, which is defined as  $W/W_{deg}$  where  $W$  is the acoustic power emitted by the transducer and  $W_{deg}$  is the power required to raise 1 degree Celsius anywhere in the beam, contributed by absorption of ultrasound (1). Most scanners have TI displayed in the screen, with an intention to predict steady state temperature rise. The maximum safest level of TI should be 6. Those machines having TI more than 6 must give a justification to FDA (9). TI is generally accurate within a factor of two but may be high as 6 in certain settings (10).

Another method of tissue heating is by convection, directly transmitting temperature to the tissue from

self heated transducer. The highest recorded temperature associated with ultrasound scanning occur with transducer self heating (11)(12). The set limit for IEC standards is 43degree Celsius. (13) TI serves as a unitless approximation of the thermal harm and is calculated by the machine in real time. (14) A TI less than 1 is generally accepted as safe (14) TI is further divided into indices based on tissue exposure: soft tissue (TIS), cranial bone (TIC), and bone (TIB). (14) We can see each of these on the machines, a single index is being displayed at a time.

## Effects of thermal harm

Core body temperature of human body is  $37 \pm 0.8$  degree Celsius and varies 0.5deg c during 24 hour period. Human body can accommodate minimal changes in body temperature. Pain due to heating occur when thermoreceptors in the skin are stimulated. Even less than 1deg c raise in temperature can be detected by the receptors in the skin. Cellular level temperature raise causes thermo-tolerance. Intracellular chaperones or heat shock proteins are produced at cellular level after few minutes of exposure to heat. There will be a decrease in natural protein synthesis and cell turnover while programmed cell death (apoptosis) increases. Above 43deg time to cause chronic damage halves for every 1deg c. (15) The thermal sensitivity to produce chronic damage varies between tissues (17). For brain and kidneys time for tissue damage is 30 min but for muscle and fat it is 240 min. (17) Not much human studies available but many laboratory as well as animals studies available. Cardiac, renal, central nerve system, musculoskeletal system anomalies of mammalian offsprings exposed to hyperthermia in utero. (18) A prospective cohort study in 1992 suggests an increased risk of neural tube defects when a pregnant women exposed to high temperature. (16)

## MECHANICAL HAZARDS

The three major mechanical effects are acoustic cavitation, gas body effects and radiation pressure effects each of them will be described separately as their mechanisms of production are different. The output display standard for mechanical effect of ultrasound is mechanical index (MI), which should be taken into consideration while selecting Ultrasound machines.

## Acoustic cavitation

Acoustic cavitation is A specific behaviour of gas bubble when placed in liquid. The size of the gas bubble changes with the pressure of the acoustic wave. It expands when the pressure of the acoustic wave decreases. contracts during the compression half-cycle of the wave. As the pressure wave changes The bubble radius also changes and ultimately the bubble becomes unstable and collapse under inertia of the surrounding liquid, which is known as inertial cavitation. In non inertial cavitation the bubble size will be stable. inertial cavitation is also associated with free radical production due to very high rapid temperature raise. (27)

## Mechanical index (MI)

mechanical index is an index for potential cavitation activity in a plane ultrasound, it is the minimum threshold for inertial cavitation and is defined as

$MI = p_r / f$  where  $f$  is the frequency and  $p_r$  is rarefactional pressure

The model used to derive this formula predicts the cavitation is unlikely when MI less than 0.7 FDA track 3 recommends maximum limit of MI to be 1.9. (20) Higher the MI as when tissues with gas filled contrast agents exposed to ultrasound chance of capillary rupture also high (21,22) At low MI stabilized micro bubbles of contrast agents scatter the ultrasonic beam effectively but there is too small amplitudes of oscillation to have harmful

effects on near by cells. At higher MI there is destabilization of the micro bubbles occurs which can be good for some diagnostic procedures but can cause damage to the cells near by

## Gas body effects

The acoustic behaviour of the medium can be altered by gas inclusions. The gas filled organs such as lungs and intestines are more likely to be damaged by gas body effects. Tissue gas interfaces reflect the ultrasonic beam this causes energy density to be doubled at the interface. Energy deposition in gas filled structures causes heating, cavitation, as well as radiation pressure. Pulsed ultrasonic waves have been demonstrated to cause destruction of lung capillaries in many animal species. In one study they concluded that the human lung capillary damage is also possible when upper end of available pulse amplitude is used. In animal studies exposure to the diagnostic ultrasound waves caused hyperemia, petechial haemorrhage, increased apoptosis, decrease in mitosis suggest both thermal and non thermal mechanisms. Small capillary damage in intestines and lungs heals very rapidly does not produce any functional change. Mechanisms of these observed Bio effects are vague hence need to be evaluated further. There are reported lung haemorrhage in mice when they are exposed to ultrasound waves.

## Radiation pressure (acoustic streaming)

When ultrasound waves pass through a medium the energy density gradient produces a local stress on the medium due to the inherent nonlinear property of acoustic waves. The force per unit volume can be calculated by the formula  $2\alpha I/c$  where  $\alpha$  is the absorption coefficient of the medium and  $c$  is the speed of the sound. The movement of the liquid when a volume force is exerted causes acoustic streaming. Acoustically induced membrane transport (phonophoresis) can

be explained by assuming disturbance of the concentration gradient occurs in liquid membrane interface. The transient displacement of the cellular attachment causes shear stress on the boundary of the ultrasonic beam produce shear wave which travel radially outward from the primary wave. There are estimates which report the radiation pressure and radiation force from the tissue absorption of highest amplitude diagnostic pulse. Due to radiation pressure effects cell to cell adhesiveness is lost leading to destruction of the tissues. Kidneys having weakest tensile strength which is 50kPa and are more susceptible to damage. Bio effects of radiation pressure have been studied, include cardiac responses, tactile sensation and altered neuronal migration. Healing of bone fracture by low amplitude millisecond pulses of ultrasound is also well established.

## Teratogenic effects to heat

Heat is a known teratogen to animals and suspected teratogen in human being. A sustained increase of maternal body temperature by 2 Deg.c results in developmental defects such as microcephaly, microphthalmia, and retarded brain development. In another study Edward has proposed that developing central nerve system is particularly susceptible to hyperthermic insult.(24)

## Ultrasound contrast agents

There are three generations of contrast agents. First generation contrast agents have air as core gas which is surrounded by fatty acid lipids or protein.(28) The micro bubbles formed by the first generation contrast agents are very labile because the active component air diffuses out of the micro bubbles. In the second generation contrast agents instead of air gases having low solubility and diffusivity are included there by the micro bubbles formed are capable of retaining the gas for longer periods of time. Optison is a second generation

## Bio effects of contrast agents

### Pulsation

contrast agent gas bodies and ultrasound pulses produce micro bubble pulsations which are responsible increased echogenicity and increased adverse effects like cavitation. theory has been developed to describe the effects of ultrasound with encapsulated gas bubbles in contrast agents such as optison .The presence of blood cells around the contrast micro bubbles have least effects on the dynamics of pulsation his theory has been used to describe scattering properties of the contrast agents (17)

### Tissue heating

The chance of thermal injury more when we are using contrast agents because the ability of the bubble to oscillate in a nonlinear path and produce heigher frequency ultrasound waves.the fluid viscosity near the oscillating bubble will also increase because of the acoustic radiation components several studies have shown that there is significant increase in heating with ultrasound contrast agents.In one study used 1.5MHzultrasoundat 0.9W/cm<sup>2</sup> on beef samples for 3 minutes and found that thetemperature raise is two times when compared to ultrasound without the contrast agents . (17)demonstrated 3 times larger lesions with contrast agent ultrasound at 1.7MHz for 20 seconds than plane ultrasound Wu (19)found temperature raise is more in presence of ultrasound contrast agents in suspension using 1.5MHz ultrasound at 3.5W/cm<sup>2</sup>.

### Cavitation and nucleation

Nucleation and cavitation is transition from restricted pulsation of gas bodies to the free pulsation of microbubbles.cavitation nuclei causes enhancement of the diagnostic ultrasonic pulses.(21)

Shells of the gas bodies remain intact at low pressure amplitude as the gas bodies oscillate. At high amplitude the gas bodies which are stabilised

canbe distrusted and forms a cavitation nuclei.The date of destabilised gas bubbles includerapid fragmentation or gradual shrinkage.(22,23) The pulsation free of micro bubbles leads to collapse due to inertia defined as inertial cavitation.(24) Mechanical index an indicator of the threshold for inertial cavitation described earlier should be as low as 0.4 In presence of contrast agents.

### Shear stress

fluid shear stress produced near the pulsating gas bodies can produce mechanical damage to the same.The microstreaming shear stress model is used to describe the bio effects including gas body activation and damage of membranes by shear stress in acoustic streaming fluid flow near oscillating gas bubble. Wu used microstreaming shear stress theory to model the effect of contrast agents micro bubbles when exposed to ultrasound waves.Destabilised micro bubble produce higher shear stress potential for destruction of the cells.(28)

## RECOMMENDATIONS

The prudent use of ultrasound does not cause any obvious deleterious effects. In view of the increased use we should be cautious in using ultrasound injudiciously for extended duration as it may cause harmful effects.

The ultrasound machines should have FDA approved standards and specifications. Regulatory bodies other than FDA are The American Institute of Ultrasound in Medicine (AIUM),World Federation for Ultrasound in Medicine and Biology(WFUMB), European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB),Australian Society for Ultrasound in Medicine (ASUM).

### General recommendations

The examination and procedures using ultrasound should only be performed by a trained and competent person who are updated in safety maters. The transducer should be switched to

freeze mode when not used in between procedure.

### Specific recommendations

The Output Display Standards first developed by AIUM 1992 in association with Electrical Manufacturers Association 1998, in order to provide safety of ultrasound usage. The ODS supported by FDA are mechanical index (MI) and thermal index (TI).

Should select machines with lowest TI and MI values and should adjust machine controls to keep them as low as reasonably achievable (ALARA principle) without compromising image quality (25). If TI and MI values could not be minimised the examination time or procedure time should be minimised to ensure the safe use. TI and MI should be continuously checked and kept as low as possible (26). The WFUMB recommends 1.5°C temperature rise as the upper threshold for clinical use. (27)

If MI is greater than 0.4 we should use minimal contrast agents or try to do the procedure without contrast agents. Hence those machines having MI 0.4 or less should be selected.

ECG should be continuously monitored in cardiac gated perfusion echo cardiography. (28)

### ANAESTHETIC IMPLICATIONS

Ultrasound scanning is the latest and exciting addition to the armamentarium of the anaesthesiology. It should be used only if indicated and not to satisfy the fancy of using these gadgets. Commonly USG is used in many situations in Anaesthesia practice like central line insertion, arterial cannulation, peripheral as well as truncal blocks and confirmation of endotracheal tube insertion. There are better ways to confirm ETT position. Hence the temptation to drag USG to unnecessary applications should be overcome. We

should reduce the procedure time and to select appropriate machines with low thermal index and mechanical index to minimise the complications associated with it.

### CONCLUSION

Recently ultrasound scan is widely used for many procedures in Anaesthesia practice. For effective use of ultrasound we should be aware of the potential hazards and measures to prevent or minimise those. Thermal index and mechanical index are two indices which measure the probability of thermal and mechanical harm respectively. We should select machines with lowest TI and MI and those output display standards should be monitored on the screen while doing procedures. Thermal injury is maximum in transcranial because TI of bone is high. Acoustic cavitation is more likely to occur with contrast agents hence MI should be less than 0.4 when we use a contrast agent. Mechanical Index (MI) or the transcranial mechanical index does not exceed 1.9 (29). Gas body effects can occur in lungs and intestines but those are self-limiting. The ultrasound should be used only when it is really indicated.

### REFERENCES

1. Barnett SB, ter Haar GR, Ziskin MC, Rott HD, Duck FA, Maeda K. International recommendations and guidelines for the safe use of diagnostic ultrasound in medicine. *Ultrasound Med Biol.* 2000; 26(3):355-366. doi:10.1016/S0301-5629(00)00156-3
2. Wood RW, Loomis AL. The physical and biological effects of high-frequency sound-waves of great intensity. *Philos Mag.* 1927;4(22):417-436. doi:10.1080/14786440908564348
3. Liebeskind D, Bases R, Elequin F, Neubert S, Leifer R, Goldberg R, et al. Diagnostic ultrasound :

effects on the DNA and growth patterns of animal cells. *Radiology*. 1981;138(2):419-423. doi:10.1148/radiology.138.2.7455123

4. Goss SA, Johnston RL, Dunn F. Comprehensive compilation of empirical ultrasonic properties of mammalian tissues. *J Acoust Soc Am*. 1978;64(2):423-457. doi:10.1121/1.382016.

5. Barnett SB, ter Haar GR, Ziskin MC, Rott HD, Duck FA, Maeda K. International recommendations and guidelines for the safe use of diagnostic ultrasound in medicine. *Ultrasound Med Biol*. 2000;26(3):355-366. doi:10.1016/S0301-5629(00)00156-3

6. Coussios CC, Farny CH, ter Haar G, Roy RA. Role of acoustic cavitation in the delivery and monitoring of cancer treatment by high-intensity focused ultrasound (HIFU). *Int J Hyperthermia*. 2007;23(2):105-120. doi:10.1080/02656730701194131

7. Nyborg WL. Biological effects of ultrasound: development of safety guidelines. Part II: general review. *Ultrasound Med Biol*. 2001;27(3):301-333. doi:10.1016/s0301-5629(00)00333-1

8. Nyborg WL. Solutions of the bio-heat transfer equation for a line source and for a boundary layer. *Ultrasound Med Biol*. 1988;14(8):741-746. doi:10.1016/0301-5629(88)90045-8

9. Srivastava S, et al. Overview of Diagnostic Ultrasound Safety. *J Ultrasound Med*. 2025;44(10):PMC12883580

10. Abbott JG. Rationale and derivation of MI and TI - a review. *Ultrasound Med Biol*. 1999;25(3):431-441. doi:10.1016/S0301-5629(98)00172-0

11. Herman BA, Harris GR. Models and measurements of transducer surface heating in diagnostic ultrasound. *IEEE Trans Ultrason Ferroelectr Freq Control*. 2002 Nov;49(11):1526-38. doi: 10.1109/tuffc.2002.1049733

12. Henderson J, Willson K, Jago JR, Whittingham TA. A survey of the temperature rise of diagnostic ultrasound scanners. *Ultrasound Med Biol*. 1995;21(5):699-705. doi: 10.1016/0301-5629(94)00155-k.

13. International Electrotechnical Commission. Medical electrical equipment – Part 2-37: Particular requirements for the basic safety and essential performance of ultrasonic medical diagnostic and monitoring equipment. IEC 60601-2-37:2007+AMD1:2015. Geneva: IEC; 2015.

14. Duck, F. A. "Hazards, Risks and Safety of Diagnostic Ultrasound." *Medical Engineering & Physics*, 2008; 30(10): 1338–1348.

15. Sapareto SA, Dewey WC. Thermal dose determination in cancer therapy. *Int J Radiat Oncol Biol Phys*. 1984;10(6):787-800. doi:10.1016/0360-3016(84)90379-1

16. Milunsky A, Ulcickas M, Rothman KJ, Willett W, Jick SS, Jick H. Maternal heat exposure and neural tube defects. *JAMA*. 1992;268(7):882–5. <https://doi.org/10.1001/jama.1992.03490070064043>

17. Fujishiro S, Mitsumori M, Nishimura Y, Okuno Y, Nagata Y, Hiraoka M, et al. Increased heating efficiency of hyperthermia using an ultrasound contrast agent: A phantom study. *Int J Hyperthermia*. 1998;14(5):495–502. <https://doi.org/10.3109/02656739809018250>

18. Edward MJ. Hyperthermia as a teratogen: a review of experimental studies and their clinical significance. *Teratog Carcinog Mutagen*. 1986;6:563-82.

19. Sokka SD, King R, Hynynen K. MRI-guided gas bubble enhanced ultrasound heating in vivo rabbit thigh. *Phys Med Biol*. 2003;48(2):223–41. <https://doi.org/10.1088/0031-9155/48/2/306>

20. Apfel RE, Holland CK. Gauging the likelihood of cavitation from short - pulse, low - duty cycle

diagnostic ultrasound. *Ultrasound Med Biol* 1991; 17:179-85.

21. Miller DL, Averkiou MA, Brayman AA, Everbach EC, Holland CK, Wible JH Jr, et al. Bioeffects considerations for diagnostic ultrasound contrast agents. *J Ultrasound Med*. 2008;27(4):611–32. <https://doi.org/10.7863/jum.2008.27.4.611>

22. Chomas, J. E., Dayton, P., Allen, J., Morgan, K., & Ferrara, K. W. (2001). Mechanisms of contrast agent destruction. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, 48(1), 232–248. <https://doi.org/10.1109/58.895928>

23. Edwards MJ Hyperthermia and fever during pregnancy 2006;76:507-16

24. Miller DL, Averkiou MA, Brayman AA, Everbach EC, Holland CK, Wible JH Jr, et al. Bioeffects considerations for diagnostic ultrasound contrast agents. *J Ultrasound Med*. 2008;27(4):611–32. <https://doi.org/10.7863/jum.2008.27.4.611>

25. American Institute of Ultrasound in Medicine. As Low As Reasonably Achievable (ALARA) Principle: Official Statement. Laurel (MD): AIUM; 2020. Available from: [https://www.aium.org/resources/official-statements/view/as-low-as-reasonably-achievable-\(alara\)-principle](https://www.aium.org/resources/official-statements/view/as-low-as-reasonably-achievable-(alara)-principle)

26. Barnett SB, Ter Haar GR, Ziskin MC International recommendations and guidelines for safe use of ultrasound in Medicine *ultrasound medical biol* 2000; 26:355-66.

27. Christman CL, Carmichael AJ, Mossaba MM, Riez P Evidence for free radicals produced in aqueous solutions by diagnostic ultrasound *Ultrasonics* 1987; 25:31-4.

28. van der Wouw, P. A., Brauns, A. C., Bailey, S. E., Powers, J. E., & Wilde, A. A. (2000). Premature ventricular contractions during triggered imaging with ultrasound contrast. *Journal of the American Society of Echocardiography*, 13(4), 288–294.

<https://doi.org/10.1067/mje.2000.103865>

29. Aubry JF, Attali D, Schafer ME, Fouragnan E, Caskey CF, Chen R, et al. ITRUSST consensus on biophysical safety for transcranial ultrasound stimulation. *Brain Stimul*. 2025;18(1):PMC12644226. doi: 10.48550/arxiv.2311.05359