Ultrasound in Pregnancy

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2014 July 15
Edited 2014 Dec 16

Ultrasound use in obstetrics started in the late 1950's as a limited diagnostic tool for identifying multiple gestation and placenta previa (Cassidy, 2006). From the first bulky machines to the sleek portable machines today, ultrasound has come a long way in its availability and cost effectiveness. Its proclaimed ability to recognize fetal abnormalities, calculate gestational age, identify the sex of the child, and recognize facial features (Cassidy, 2006) has boosted its popularity in society's eyes. There appears to be a conflict of beliefs between the proponents declaring its safety and its value as a diagnostic tool, and the opposition's position pertaining to safety, physiological impact and long - term effects it may have on a child (Cassidy, 2006).

Proponents rely on research that shows there doesn't seem to be a correlation between adverse maternal outcomes, perinatal outcomes, or growth and neurological development during infancy with the use of ultrasound during pregnancy (Torloni, 2009) in women with low risk pregnancies. Whereas, the opponents against routine ultrasound look at the research as being inadequate for the equipment currently being used, exposure intensity, duration, frequencies, experience levels of technicians, or results from mammalian studies (Abramowicz, 2014). Some questions have been raised regarding whether or not Doppler ultrasounds are harmful to humans. "Have there been descriptions of harmful effects of Doppler ultrasound (DUS) in humans (children or adults) who were insonated *in utero*? It appears to be no, but a lack of demonstration does not equal a lack of effects" (Abramowicz, 2014). What type of subtle effect will DUS have on a person? The answer is "neither theoretic calculations nor experimental results can yield unambiguous and definite evidence that fully guarantees the safety of ultrasound diagnostics, particularly in regards to delayed, subtle effects" (Abramowicz, 2014).

Research pertaining to safety was done with equipment standards prior to 1992, "when the acoustic potency of the equipment used was lower than in modern machines" (Torloni, 2009). "However, it must be pointed out that all human epidemiological studies were conducted with commercially available devices predating 1992, with acoustic outputs not exceeding an intensity of 94 mW/cm2" (Kresser). "Modern ultrasound equipment acoustic outputs allow intensities of up to 720 mW/cm2" (Kresser). No human studies on the safety of ultrasound with the newer higher intensities have been conducted (Abramowicz, 2014, Kresser).

The term Doppler is used for two distinctive technical devices with extremely different acoustical potencies. One is the hand held fetal Dopplers and the other is a wand used in conjunction with an ultrasound machine. People assume that Doppler equates to a hand held fetal Doppler rather than a wand used on an ultrasound machine. This causes confusion for people when the term is interchanged.

Definitions:

Definition of Doppler Ultrasound: A Doppler ultrasound is the wand used on an ultrasound machine with acoustical potency of 300 Hz to 10 GHz. This Doppler uses continuous waves inducting a higher and longer level of exposure. The exposure limits used by the FCC are expressed in terms of "Specific Absorption Rate 'SAR', electric and magnetic field strength and power density for transmitters operating at frequencies from 300 kHz to 100 GHz" (FCC Safety Board). "Inconsistencies in the training of technicians will influence the level of exposure a fetus encounters (Kresser). "

Definition of Fetal Doppler: A fetal hand held Doppler that many midwives use has an acoustical potency of 2 ‑ 3 MHz, less than 1% of the energy emitted from a doppler ultrasound. "Hand held non ‑ imaging fetal Dopplers hold no risk (Abramowicz, 2014). "

The FCC has determined which radio frequency (RF) levels are considered safe. The quantitative term used to measure the rate by which RF energy is actually absorbed in a body is called the "SAR". 70 MHz is the optimal frequency for the human body to absorb. Because of this "resonance" phenomenon and consideration of children and grounded adults, RF safety standards are generally most restrictive in the frequency range of about 30 to 300 MHz" (FCC Safety Board). Ultrasound works on RF, including the above ‑ mentioned frequencies.

Acoustical streaming is one of the detrimental effects of using ultrasonic energy. "Acoustical streaming involves a jet of fluid created by the ultrasound wave, which causes a mechanical shearing force at the cell surface (Kresser)." Acoustical streaming "takes … about a minute to raise temperature to its peak, time is very important." (Abramowicz, 2014). Another issue influencing the heating factor is tissue density – soft tissue versus inducing the ultrasound beam through bone (Abramowicz, 2014). "While the effect of this force is not fully understood, research suggests that it may change cell permeability and have adverse effects on both early and late prenatal and postnatal development (Kresser)."

According to the research done by Kresser, when modern ultrasound equipment is used at maximum capacity, the chances of biological damage from the acoustical outputs include "significant temperature increases within the tissue." Greater risk of induction of thermal effect happens "when fetal bones are intercepted with an ultrasonic beam and significant temperature increases can occur in the fetal brain especially in the second and third trimesters (Kresser)." The increase of the whole-body temperature of up to 4.5 °F during normal pregnancy is presumed to be safe. "Research suggests that elevating body temperature by 1.8 – 2.7 °F during an ultrasound is presumed safe (Kresser)". "However, pulsed or continuous ultrasound energy on a fetus's brain in second or third trimester may increase the temperature by 2.5 to 10.4 °F, which is outside the safety limits of cellular heating (Kresser)." "In addition the absolute increase in temperature, duration of heating and thermoregulatory capacity of the body are the important determinants of the harmful levels of tissue heating" (Environ Health Perspect, 2004)." "Laboratory studies suggest that adverse biologic effects can be caused by temperature rises in tissue that exceed 1.8 °F above their normal temperatures (Environ Health Perspect, 2004)." Studies on mice and chicken eggs have shown hyperthermia have caused causes short and long - term effects (Abramowicz, 2014).

Ultrasound is being used regularly as routine prenatal care including 3D and 4D imaging. "These forms of ultrasound are being marketed for getting baby's first photo with facial features so you know what your baby looks like before they are born (Cassidy, 2006)." Marketing feeds into society's need of instant gratification. When you combine it with curiosity of the sex and the novelty of the higher tech ultrasounds, this all contributes to a craze of multiple and unnecessary ultrasounds during the course of pregnancy. This does not take into consideration other factors contributing to multiple ultrasounds regarding the moneymaking opportunity and the convenience for doctors to check on the well being of babies without a connection with their patients. ACOG and other organizations have established the following recommendations for its use: A client/ patient should receive a scan only when medically indicated; One should keep their exposure as minimal as possible.; A technician should start a scan at the lowest possible output (default) and it only be increased as necessary; Clients/patients should be extremely cautious when having Ultrasound Doppler exposure in the first trimester. I personally believe that ultrasound, when medically indicated, is an awesome intervention.

X - ray was once used as a diagnostic tool during pregnancy to later be discontinued because it was dangerous to the fetus (Cassidy, 2006). As I have considered the energy that is being introduced into the pregnant woman's body and the harmful effects that energy has, I believe 20 years from now ultrasound will be seen in a similar light as x-ray. The damage that is caused by ultrasound through "improvements in the equipment with higher intensity and increased frequencies with combined duration, increases its devastating effects to the cell even down to the DNA and RNA levels" (Kresser, FCC Safety Board). The damage to the DNA and RNA inhibit the cells from being able to replicate without mutations. At some point the damaging effects will be recognized, acknowledged and could be linked to Autism, Dyslexia, or other learning disabilities associated with the harmful effects on the fetal brain development that are not fully understood, due to cellular hyperthermia or acoustical streaming.

Appendix A:

FCC RF safety levels compared with power/exposure in U/S. U/S frequency ranges are from 300 Hz to 10 GHz. Studies have not been published to show the relationship of ultrasonic doppler frequencies to power density and exposure time with cellular, physiological or developmental damage. However, one can draw a conclusion to the possibility when comparing it to the safety levels recommended by the FCC.

Table 1: Limits for Maximum Permissible Exposure (MPE)

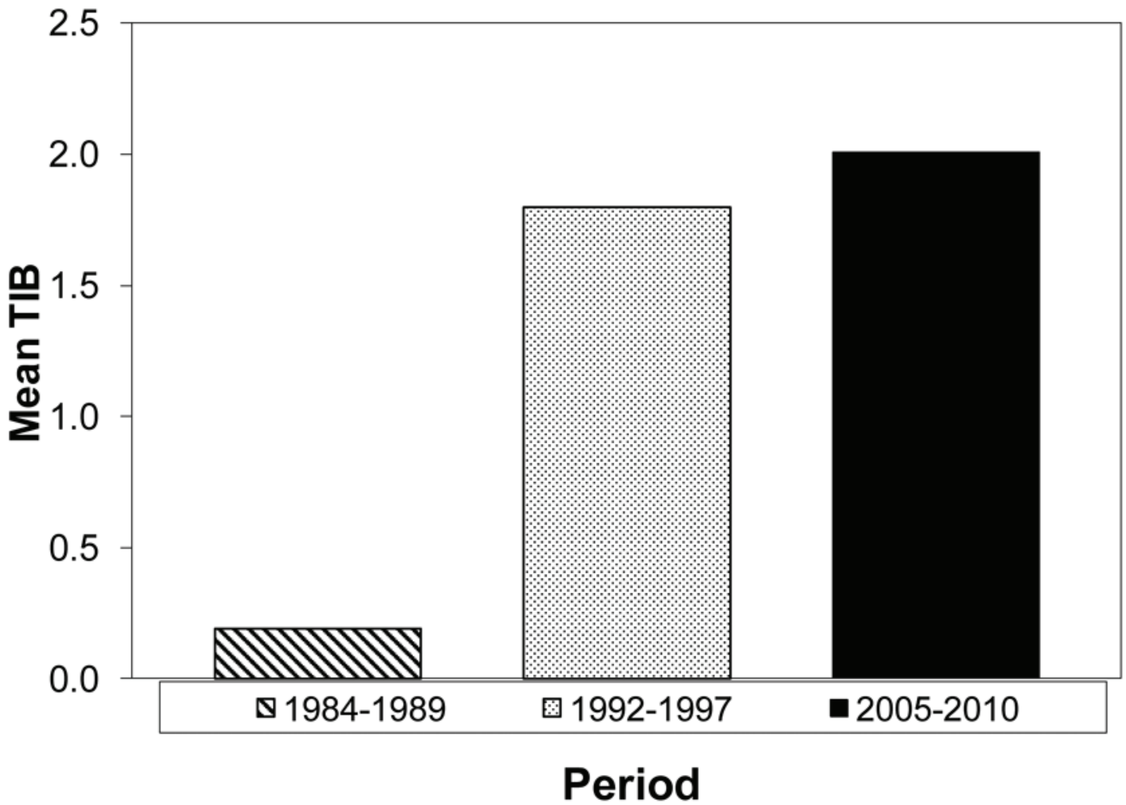
Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposure				
0.3–3.0	614	1.63	*(100)	6
3.0–30	1842/f	4.89/f	*(900/f2)	6
30–300	61.4	0.163	**1.0	6
300–1500			f/300	6
1500–100,000			5	6
(B) Limits for General Population/Uncontrolled Exposure *(Author's note: These limits presume greater distance between human subject and source of exposure than in section (A) above, see Table 2 to compare how the safe threshold power levels for all frequencies drop with closer distance - such as occur during an ultrasound.)*				
0.3–1.34	614	1.63	*(100)	30
1.34–30	824/f	2.19/f	*(180/f2)	30
30–300	27.5	0.073	0.2	30
300–1500			f/1500	30
1500–100,000			1.0	30
f = frequency in MHz * = Plane-wave equivalent power density ***Author note: this should read 1W* (FCC 13-39)				

Table 2: Threshold Powers (mW) at Selected Frequencies (GHz) and Distances from 0.5 to 20 cm

Frequency (GHz)	Distance (cm)																
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12.5**	**15**	**17.5**	**20**
0.3	39	65	88	110	130	150	180	220	250	280	310	340	360	430	490	550	610
0.45	22	44	67	89	110	130	180	230	270	320	360	410	460	570	690	800	920
0.835	9.2	25	44	66	90	120	170	240	310	390	470	550	640	900	1100	1400	1700
0.9	8.3	23	42	63	88	110	170	240	320	400	480	570	670	900	1200	1500	1800
1.45	4.3	15	30	50	74	100	170	250	350	460	580	720	870	1300	1800	2300	3000
1.8	3.5	13	26	45	67	94	160	240	340	450	570	710	860	1300	1800	2400	3060
1.9	3.4	12	26	44	66	92	160	240	330	440	560	700	850	1300	1800	2400	3060
2.45	2.7	10	22	38	59	83	140	220	310	420	540	670	820	1300	1800	2400	3060
3	2.3	9.0	20	35	53	76	130	210	290	400	510	650	790	1200	1700	2400	3060
5.2	1.5	6.3	15	26	42	61	110	170	250	350	460	590	730	1200	1700	2300	3060
5.8	1.4	5.9	14	25	40	58	110	170	250	340	450	580	720	1100	1700	2300	3060

(FCC 13-39)

Table 3: Changes in Output Levels of Ultrasound Devices, Rated in Thermal Index for Bone (significant for fetal imaging safety).



(Cibull, 2013).

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