Diagnostic and Interventional Imaging (2018) xxx, xxx—xxx

REVIEW /*Interventional imaging*

Shear wave elastography safety in fetus: A quantitative health risk assessment

M. Issaoui[a], A. Debost-Legrand[a,b], K. Skerl[a], B. Chauveau[a,c], B. Magnin[a,c], A. Delabaere[a,b], L. Boyer[a,c], M.-P. Sauvant-Rochat[a,b,d], D. Lémery[a,b,*]

[a] *CNRS-UMR 6602, institut Pascal, université Clermon-Auvergne, Axe TGI, 63000 Clermont-Ferrand, France*
[b] *Pôle Femme et Enfant, centre hospitalier universitaire de Clermont-Ferrand, 63003 Clermont-Ferrand, France*
[c] *Pôle radiologie, centre hospitalier universitaire de Clermont-Ferrand, 63003 Clermont-Ferrand, France*
[d] *Département de santé publique et environnement, université Clermont-Auvergne, faculté de pharmacie, 63000 Clermont-Ferrand, France*

KEYWORDS
Elastography;
Shear waves;
Evaluation risk;
Ultrasound;
Health risk assessment

Abstract
Purpose: To identify the effects of shear wave elastography in the fetus for evaluation in widespread use.
Materials and methods: The Health Risk Assessment method proposed by the National Research Council was used with literature to evaluate the safety of shear wave elastography for the fetus regarding its potential effects in human tissues.
Results: The experimental and epidemiologic data from 25 articles showed that shear wave elastography maintained the same thermal effect as pulsed Doppler ultrasound already authorized in obstetrics, and that cavitation effect on fetal tissue is improbable. Nonetheless, the vibratory character of shear waves could induce displacement of fetal tissue while potential effects of very short duration energy peaks of the radiation force focused wave front remain unknown.
Conclusion: The actual knowledge does not provide enough information to assess the effects of shear wave elastography on fetal tissues, thus these points have to be explored by further experimental studies.

* Corresponding author. Pôle Femme et Enfant, centre hospitalier universitaire de Clermont-Ferrand, 63000 Clermont-Ferrand, France.
E-mail address: dlemery@chu-clermontferrand.fr (D. Lémery).

https://doi.org/10.1016/j.diii.2018.04.013
2211-5684/

Among the ultrasound techniques applied in medicine, elastography, or ultrasound palpation first appeared at the beginning of the 1990s [1]. It has been shown that ultrasound can provide real-time information on the elasticity of soft tissue as well as supplementary evidence about a medical diagnosis [2]. Its physical principle is based on the assessment of Young's modulus, noted as *E* and measured in kPa (kilopascals), a physical parameter characterizing the degree of stiffness of a tissue.

Shear wave elastography (SWE) is a relatively new approach to this imaging technique [3]. A shear wave is a type of mechanical wave that propagates in elastic media by causing layers of tissue to slide in relation to one another. It moves by successive oscillations perpendicularly to the axis of the wave front displacement. SWE takes advantage of the focusing of an ultrasonic compression wave, which generates radiation force in dissipative biological media. This radiation force pushes the tissue locally, for some dozens of microns, in the target focal zone, for a period of around 100 microseconds (μs). Then the tissue relaxes by creating a shear wave that propagates perpendicularly to the axis of the ultrasound beam. In this technique, the propagation stage of a shear wave is visualized by ultrafast ultrasound imaging able to capture the wave front in the approximately 10 milliseconds (ms) it takes to propagate over several centimeters at a speed on the order of 1 m/s [4]. It has demonstrated its reproducibility and clinical interest for the characterization of a mass in superficial organs, such as the breast, as well as in deep organs, such as the liver [5—8].

As of today, no health agency has released an opinion about the principle of using SWE in obstetrics. This technique might nonetheless be useful in perinatal health. Numerous published articles have already studied tissues, such as the cervix, that are accessible to methods of elastography necessitating the direct compression of an organ by an ultrasound probe [9]. On the other hand, in the absence of direct contact with the fetus, theoretically no method except SWE can enable *in utero* assessment of tissue elasticity [10—12].

Regardless of its clinical relevance, and like any new technologies used where developing biological tissue may be at risk, it is necessary to demonstrate its safety before allowing its utilization in routine obstetric practice. Current knowledge about ultrasound waves has led to identify two types of potential adverse effects on biological tissues: thermal and mechanical [13]. With that being noted, in the imaging conditions used thus far in humans, no ultrasound-related adverse effect on the fetus have been shown either by epidemiologic studies or by extrapolation from experimental studies *in utero* or in animals [14].

To date, it is relevant to consider the health risks associated with SWE with the potential widening of its use in obstetrics and fetal ultrasound, so a health risk assessment must be considered in a timely manner. The health risk assessment process has slowly become the international reference tool for evaluating health risks of chemical, biological, or physical (and thus radiologic) origins. This structured process was developed in the early 1980s by the US National Academy of Sciences, which defined it as a methodical procedure to summarize the scientific knowledge available to assess the health effects resulting from the exposure of a population or individuals to a potentially dangerous substance, agent, or situation (National Academy of Sciences NAS, 1983) [15].

The health risk assessment has been used relatively sparsely for medical radiology applications. The aim of this review was to identify the effects of SWE in the fetus for evaluation in widespread use.

Material and methods

Information sources

Our review of the literature searched from several databases (PubMed Medline, Google Scholar, Cochrane) using the following key words: ''elastography''; ''shear wave''; ''biological effects of ultrasound''; ''fetal ultrasound''; ''health risk assessment of elastography''; ''pulsed Doppler''; ''safety''; and ''assessment''. We started by identifying all articles in French and English published over the past 25 years (1990—2017) returned by the databases; as well as the gray literature from governmental sites and those of scientific societies, that are:

- reports from the French national authority for health (HAS);
- US Food and Drug Administration (FDA);
- American Institute of Ultrasound in Medicine (AIUM);
- British Medical Ultrasound Society (BMUS);
- the European Committee for Medical Ultrasound Safety (ECMUS).

Eligibility criteria

The initial screening was based on a reading of the abstracts, in order to consider only those articles describing either the physics of shear waves or the biological effects of ultrasound. The articles selected through this first screening were then read in totality to identify those relevant to our study. Articles were eligible if they presented experimental and observational studies (qualitative and quantitative, prospective and retrospective) associated in any manner with obstetric ultrasound, the basic physical principle of elastography, and the technique of shear wave elastography, as well as the effects of ultrasound on biological tissues and the health risks associated with ultrasound techniques. Literature reviews, opinions, and guidelines from health authorities and scientific societies were also considered.

To enable us to conduct a quantitative health risk assessment (qHRA approach), for each included study we considered the data allowing to specify the mechanism of action of the ultrasound waves (considered the ''hazard''), and the biological and toxicological effects (considered to be ''critical effects'') obtained from in vivo experimental and observational studies.

Method of health risk assessment

Our analysis is based on the health risk assessment process described by the National Research Council and seeks to determine both how exposure might cause health effects and what these effects might be. Our literature review led us to conduct a qHRA according to the standard method insofar as the data allowed. It was structured into four steps:

Please cite this article in press as: Issaoui M, et al. Shear wave elastography safety in fetus: A quantitative health risk assessment. Diagnostic and Interventional Imaging (2018), https://doi.org/10.1016/j.diii.2018.04.013