Abstract

Pulsed diagnostic ultrasound has been widely used for fetal imaging for less than 20 years. While no harmful results have been documented in patients, several laboratory investigations suggest that it does have biological effects. Furthermore, some studies do not support the use of routine ultrasound to evaluate gestational age, detect twins or diagnose intrauterine growth retardation. Its value for detection of congenital anomalies is clouded by many unanswered questions. Imaging ultrasound is valuable in modern obstetrics, but should be used selectively rather than routinely until its safety and utility are clarified. Doppler fetal heart monitoring with continuous wave ultrasound also needs critical appraisal.

Sommaire

L'échographie au moyen d'ultrasons a été largement utilisée pour visualiser le fœtus et ce depuis moins de vingt ans. Bien qu'aucun dommage n'ait été rapporté chez le fœtus suite à cette utilisation, plusieurs recherches en laboratoire suggèrent que cette technique produit des effets biologiques. De plus, certaines autres études ne recommandent pas l'usage routinier de l'échographie pour évaluer l'âge de la grossesse, déceler une grossesse gémellaire ou diagnostiquer un retard de croissance intra-utérin. Sa valeur de dépistage des anomalies congénitales reste douteuse. On doit utiliser l'échographie en obstétrique moderne tout en le faisant de façon sélective plutôt que de routine jusqu'à ce que la question de l'absence d'effets biologiques à long terme soit satisfaite. Les effets biologiques du monitoring du cœur fœtal par Doppler avec ultrasons continus devraient aussi être évalués objectivement.

Introduction

Enormous progress in medical science and obstetrical practice has resulted in a spectacular reduction in perinatal morbidity and mortality over the past 100 years, but some well-intentioned interventions have had unforeseen adverse effects. An instructive example is diethylstilbestrol (DES) for bleeding in early pregnancy. Enthusiasm for innovations should be carefully measured.

How Safe is Diagnostic Ultrasound?

A Popular Misconception

Worry-free attitudes to diagnostic ultrasound reflect a belief that current equipment produces low acoustic intensities, which are known to be harmless. The underlying notion of a safe threshold appears to be supported by the first sentence of the 1978 statement on mammalian in vivo biological effects issued by the Bioeffects Committee of the American Institute of Ultrasound in Medicine, reaffirmed (1) in October 1982:

"In the low megahertz frequency range there have been (as of this date) no independently confirmed significant biological effects in mammalian tissues exposed to intensities below 100 mW/cm²."**

*Spatial peak, temporal average (SPTA) as measured in a free field in water
**Milliwatts per square centimetre.

The booklet from which this quotation is drawn indicates in further discussion (2) that the value of 100 mW/cm² cannot be considered as an established safe threshold. At a practical level, the cautionary addendum has received little attention.

Surveys of SPTA intensities produced by imaging equipment give a range of 0.12 to 200 mW/cm² (3,4a). For Doppler fetal monitoring devices, the range is 0.6 to 75 mW/cm² (4a).

Doppler Versus Imaging Ultrasound

Doppler monitoring systems emit ultrasound continuously. Imaging units emit short pulses with intensities about 1000 times higher than the time-averaged values usually quoted, and pulse intensity may be of particular biological importance (4b,5). Doppler systems are directed at the fetal heart and are used mainly in the third trimester.
whereas imaging ultrasound is directed at many fetal structures and is commonly used earlier in pregnancy. It is therefore invalid to say that as long as prolonged Doppler monitoring is widely accepted, the risks of brief diagnostic examinations can be dismissed as negligible.

**Experimental Studies — Limitations and implications**

Table 1 lists the findings of several articles that have shown biological effects of pulsed diagnostic ultrasound in mammalian systems (mainly in vitro). We must, however, be cautious in drawing inferences from these studies for several reasons:

1. To my knowledge, the experiments have not been repeated by others. The importance of independent confirmation is expressed in the bioeffects statement previously quoted. There have been disturbing reports that were not confirmed when different investigators reproduced the experiments.

2. Any clinical relevance is largely speculative.

3. There are many other articles in which authors have been unable to demonstrate biological effects of imaging ultrasound. In particular, preliminary results of a Canadian clinical study involving thousands of children who were exposed in utero and followed for several years show no harmful results (13).

4. Ultrasound is markedly weakened by passing through the mother before reaching the fetus.

What these articles do is underscore our inability to make confident reassuring statements about the clinical safety of obstetrical ultrasound examinations. We are unable to say that the human fetus is undamaged by diagnostic ultrasound. "To date, very little information from adequately controlled human epidemiological studies is available... the question of subtle and/or long-term effects remains unanswered" (4c).

**General Principles in Patient Selection**

**See Addendum**

When one anticipates a specific benefit from ultrasound examination that cannot be obtained by safer means, he should do it.

When one does not anticipate a specific benefit from ultrasound examination, he should not do it.

Surely there is nothing radical nor original about these principles. "Safer" applies as well to careful clinical evaluation, urine tests, and (probably) small volume blood tests. The unresolved bioeffects question requires a critical analysis of any proposal for the routine use of ultrasound in pregnancy. A critical analysis of the justifications for routine ultrasound is required.

**"Indications" for Routine Ultrasound**

**Background**

Screening ultrasound was initially advocated for evaluation of gestational age and twin detection (14). Disappointment with clinical diagnosis of intrauterine growth retardation led to some enthusiasm for this purpose (15, 16). With improvements in real-time equipment, it has assumed an important role in the diagnosis of congenital anomalies (16). These can be divided into neural tube defects (NTD), where the implication is termination of pregnancy, and non-NTD anomalies, where the implication is an improvement in fetal or postnatal status by various treatment approaches.

**Gestational Age Evaluation**

Knowledge of gestational age is a basic requirement in obstetrics. One-third or more of patients have some cause to be uncertain of their dates. In these cases, an ultrasound examination around 18 weeks is strongly advisable. The assertion that no patient's dates are reliable, however, is unwarranted. Nearly all the crown-rump length and biparietal diameter standard curves are constructed using information from women with known reliable dates. It is illogical to turn around and say that the underlying clinical data are unsatisfactory.

Figure 1 is the regression curve calculated for 214 data points on 80 patients for crown-rump length versus menstrual age taken from the original study by Robinson (17). If we treat this respected ultrasound method as the

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**TABLE 1**

**BIOLOGICAL EFFECTS OF PULSED DIAGNOSTIC ULTRASOUND**

<table>
<thead>
<tr>
<th>Whole organism</th>
<th>Rat fetal growth inhibition (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular behavior</td>
<td>Reduction in cellular attachment to plastic (7)</td>
</tr>
<tr>
<td>Disturbed cellular growth patterns in tissue culture (6)</td>
<td></td>
</tr>
<tr>
<td>Depression of phagocytosis (9)</td>
<td></td>
</tr>
<tr>
<td>Reduced tumor transplantability (10)</td>
<td></td>
</tr>
<tr>
<td>Cellular structure</td>
<td>Altered surface morphology (11)</td>
</tr>
<tr>
<td>Genetic material</td>
<td>Disturbances in cellular DNA (8)</td>
</tr>
<tr>
<td>Induction of sister chromatid exchanges (12)</td>
<td></td>
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</table>
new reference standard for gestational age, we can see that the author was consistently able to select patients on clinical grounds whose dates were no more than a week out. The same conclusion can be reached from data presented in other articles (18,19).

Several authors have compared ultrasound methods and good menstrual history for prediction of date of spontaneous delivery, a simple but not entirely satisfactory approach. Sampling of such studies (20,21,22) does not provide a convincing consensus favoring ultrasound. Even if ultrasound is slightly better, is an average of two days increase in precision clinically useful? The primary challenge is the development and dissemination of rigorous and reproducible criteria for accepting a patient's dates as reliable. The exact roles of menstrual history (with close attention to pitfalls), early clinical examination and early pregnancy testing deserve scientific scrutiny.

Twins (Multiple Pregnancy)

Twin pregnancies are vulnerable to many complications, especially prematurity and growth retardation. The frequency with which twins are missed before the onset of labor using conventional clinical means ranges up to about 50 per cent (23). One group, however, has taken a systematic approach to diagnosis by identifying high-risk patients on the basis of fundal height and abdominal girth measurements (over the 90th percentile) and referring them for ultrasound (24). Retrospective analysis of ultrasound records showed that in patients who began their antenatal visits early, all except one of 133 twin pregnancies were identified by 28 weeks. This is a matter that requires more study. In the interim, the vigilant clinician is entitled to maintain a policy of selective ultrasound examination for twin detection.

Intrauterine Growth Retardation (IUGR)

Fetuses that are small for dates are at an increased risk, especially from asphyxias. It is important to decide on the terms of reference to be used in comparing clinical and ultrasound evaluation for IUGR. Sensitivity and specificity values, which are not influenced by prevalence in the population under study (25), are most appropriate. Sensitivity of 86 per cent and specificity of 90 per cent for IUGR detection have been obtained by standardized fundal height measurement using a tape measure (26). Reviewing studies involving adequate numbers of patients, I cannot find ultrasound methods for IUGR diagnosis that have sensitivity and specificity values, or comparable statistics, which are appreciably superior. (There may be an exception (15), but this method requires static scanner equipment, which is expensive and otherwise of limited value.) Admittedly, these are among the most favorable figures available for clinical detection of IUGR, but the basic point remains: it should be possible to identify clinically a large group of normal pregnancies in which ultrasound is unnecessary to evaluate fetal growth.

Neural Tube Defects (NTD)

Anencephaly is easily identified by ultrasound in the second trimester, but spina bifida can be a diagnostic challenge requiring examiner experience and good equipment (27). The timing of the examination may also be relevant (28). There are two alternatives to routine ultrasound for NTD detection:

1. Maternal serum alpha-fetoprotein (AFP) screening, which can detect up to 90 per cent of open NTDs (29).
2. Primary prevention with dietary improvements (30), folic acid (31) or multivitamins (32). While these ap-
proaches have many problems, they are at least as promising as routine ultrasound.

Non-NTD Congenital Anomalies

A variety of non-NTD congenital anomalies can be identified by ultrasound (16) and there is therapeutic relevance in many instances (33). Fetal surgery for hydrocephalus and hydronephrosis has aroused considerable interest. Before routine ultrasound can be promoted for the detection of non-NTD anomalies, however, a number of questions and issues need to be dealt with:

1. Clarification of the real net benefits resulting from fetal treatment, especially surgery, is needed (34).
2. Diagnostic alternatives to ultrasound should be explored at the screening level. For example, abnormalities in uterine size for dates can be a tip-off for fetal malformations (35).
3. How much ultrasound examiner expertise can reasonably be expected in an everyday setting? While detection of a major degree of hydronephrosis or hydrocephalus does not usually present difficulties, analysis of congenital heart disease in utero is beyond the capability of most ultrasonographers.
4. What is the optimum timing of examination if we are basically interested in non-NTD anomalies? It may be around 26 weeks, which is far from ideal for conventional purposes such as dating or IUGR detection.
5. Ultrasound examination directed at searching for anomalies is liable to be anticipated with anxiety by the patient. Unfortunately, our capacity for reassurance on the basis of a normal examination is limited (36). For example, we cannot rule out Down syndrome, uncomplicated intestinal malrotation or a host of inborn errors of metabolism.
6. Finally, we cannot ignore issues of financial cost versus benefit when considering widespread use of sophisticated technology for detecting relatively rare disorders.

Doppler Fetal Monitoring

As a radiologist, I may be out of my depth in this area, but I am obliged to comment in the interests of consistency. Two points come to mind. The first concerns the value of any kind of continuous fetal heart monitoring during labor, especially in low-risk deliveries. While opinions differ, there is evidence that it does not result in improved outcome (37,38,39). Second, it is hard to believe that modern technology cannot provide satisfactory tracings from audible fetal heart sounds in most patients. Pressure on manufacturers from the physician-consumer would likely produce results.

Hand-held Doppler devices used in doctors’ offices also merit attention. They should be used only to provide valuable information not obtainable by safer means, especially early in pregnancy.

Conclusion

This article is mainly intended to provoke thought and discussion. On a practical note, Table 2 lists my view of the basic indications for diagnostic ultrasound in pregnancy; they are similar to those proposed by the Society of Obstetric and Gynecologic Ultrasound (36). Ultrasound exposure in the first trimester should be avoided, unless there are specific indications such as suspicion of ectopic pregnancy.

| TABLE 2 |
| PROPOSED INDICATIONS FOR IMAGING OBSTETRICAL ULTRASOUND |

| Uncertainty about gestational age |
| Unexplained bleeding |
| Clinical suspicion of: |
| multiple pregnancy |
| growth retardation |
| fetal anomaly |
| malpresentation (in labor or near term) |
| oligohydramnios or polyhydramnios |
| fetal death |
| ectopic pregnancy; mole |
| Guidance for amniocentesis |

Acknowledgements

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Also Recommended:

Addendum

Post-publication correction: The section entitled "General Principles in Patient Selection" was supposed to read:-

When you anticipate a specific benefit from ultrasound examination that cannot be obtained by safer means, do it.
When you do not anticipate a specific benefit from ultrasound examination, do not do it.

Surely there is nothing radical or original about these principles. "Safer" boils down to careful clinical evaluation, urine tests, and (probably) small volume blood tests. The unresolved bioeffects questions require a critical analysis of any proposals for the routine use of ultrasound in pregnancy.