Safety of Diagnostic Ultrasound

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Ultrasound has been used for diagnostic purpose since the late 1950s. Because of its low cost, capability of real time image display of anatomy and blood flow information, and, its apparent lack of bio-effects, ultrasound is a fast growing imaging modality. The impact of ultrasound in the care of women and children is most obvious.

Nowadays, like most well developed countries, almost every pregnant woman will have routine antenatal ultrasound. The trend of increasing use of ultrasound also happens in other specialties. Most of the ultrasound machines are now equipped with Doppler functions. The widespread use of Doppler ultrasound raises further concern because Doppler is associated with increase in exposure parameters as compared to the usual B mode.

Bio-effects

The two main mechanisms that may produce biological change are heating and cavitation.

Heating

Ultrasound can raise temperature of tissue and this can be quite significant at bone surfaces because of the higher energy absorption in bone. It is quite unlikely that the machines used for diagnostic purpose will lead to significant heating, but the potential of Doppler ultrasound to heat tissue at the top end of their available outputs has to be emphasized.

Tissue heating is of greatest concern in obstetrical examinations. Studies have shown embryos of many mammals susceptible to heat damage. The effect of heating depends on the stage of embryo development, the temperature rise and the time of exposure. Abortion is a well known consequence of heating. Hyperthermia is also found to be a teratogen in a number of mammalian studies. Early embryos are more susceptible to heating than late embryos because of more intense cell proliferation. However, it is quite unlikely that the usual diagnostic ultrasound examination can heat the embryo or the fetus significantly and ultrasound can be considered safe. However, caution should be exercised where Doppler examinations are to be performed. The thermal index (TI) is a number to provide an estimate of the tissue temperature rise in centigrade which might be possible. Three forms of TI are available: TIS, for soft tissue exposures; TIB, which is used when bone lies near the beam focus; and TIC, for the heating of bone situated close to the transducer. As the risk of adverse effects increases with the length of exposure time, if examination time is kept as short as possibly achievable, the possibility of adverse effects due to heating is unlikely.

Cavitation

Cavitation means formation of 'bubbles' when tissue is exposed to ultrasound. The bubbles may oscillate and explode leading to tissue damage. Ultrasound induced lung and intestinal haemorrhage in animals have been reported. However, there is no known risk of lung haemorrhage in the fluid filled human fetal lung that is exposed to diagnostic ultrasound during a routine obstetrical examination. But, in conditions under which humans are more likely to have lung haemorrhage, e.g. in the preterm infant, application of ultrasound may pose an increased risk. Again, by limiting the examination time, the risk of any possible adverse effect is unlikely. Mechanical index (MI) has been formulated to assist users in evaluating the likelihood of cavitation related adverse effects. MI is now displayed in many of the modern ultrasound machines. The operator can then set the machine accordingly with the aim of achieving a quality image with as low as possible Index.

Epidemiological Studies of the Effects of Ultrasound Exposures in Human

There is no epidemiological evidence to indicate any association between diagnostic ultrasound exposure during pregnancy and reduced birth weight, childhood malignancies or neurological maldevelopment. However,

a meta-analysis of data shows a weak association between increased incidence of nonright-handedness among boys and prenatal exposure to ultrasound. Nevertheless, these results required further evaluation and a prospective randomized trial is needed to answer this question with confidence.

On Safe Use of Ultrasound

1. As the probability of biological effect due to thermal effects and cavitation effects increase with the time of exposure, it is prudent to keep the transducer contact with the skin while transmitting as short as possible.
2. The acoustic output should be kept as low as possible. For all ultrasound examinations, the machines should be set to give the lowest output and compensated by high receiver gain.
3. The US Output Display Standard requires that at least one of the indices, i.e. MI, TI, is displayed on the equipment monitor, depending on the mode of operation, clinical application and the maximum value that the indices may achieve. These indices provide the operator important information on the acoustic outputs and facilitate the operator to employ ALARA (as low as reasonably achievable) principle. **Always try to use the lowest acoustic output and the shortest examination time necessary to obtain the essential diagnostic information.**
4. The American Institute of Ultrasound in Medicine (AIUM) made a statement on prudent use of ultrasound in 1999. *The AIUM advocates the responsible use of diagnostic ultrasound. The AIUM strongly discourages the non-medical use of ultrasound for psychosocial or entertainment purposes. The use of either 2D or 3D ultrasound to only view the fetus, obtain a picture of the fetus or determine the fetal gender without a medical indication is inappropriate and contrary to responsible medical practice. Although there are no confirmed biological effects on patients caused by exposures from present diagnostic ultrasound instrument, the possibility exists that such biological effects may be identified in the future. Thus ultrasound should be used in a prudent manner to provide medical benefit to the patient.*

Clinical Safety

The AIUM made a statement on clinical safety in 1997.

Diagnostic ultrasound has been in use since the late 1950s. Given its known benefits and recognized efficacy for medical diagnosis, including use during human pregnancy, the American Institute of Ultrasound in Medicine herein addresses the clinical safety of such use :

There are no confirmed biological effects on patients or instrument operators caused by exposures from present diagnostic ultrasound instruments. Although the possibility exists that such biological effects may be identified in the future, current data indicate that the benefits to patients of the prudent use of diagnostic ultrasound outweigh the risks, if any, that may be present.

Conclusion

Diagnostic ultrasound is safe but it seems logical to adopt a conservative approach giving the uncertainties in bioeffects data. The use of ultrasound for psychosocial or entertainment purposes should be discouraged, and like any other imaging examinations, there should be clinical indication for the examination. The benefit should outweigh any possible risks if there is a clear indication. In view of the wide margin of safety of diagnostic ultrasound, the benefit versus risk ratio is most favourable in comparison to other imaging modalities. All ultrasound examinations should be performed under the ALARA (as low as reasonably achievable) principle and all operators should be trained to operate their equipment accordingly.

Early Childhood Caries

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Dental caries in infants and children can be painful, serious and debilitating (Brice et al 1996). The first comprehensive description of caries in infants, which was termed "nursing bottle mouth" was published in 1962 (Fass 1962). In this paper, the now well recognized caries pattern was said to affect "... all the primary upper anterior teeth, upper and lower primary first molars and the lower primary canine teeth...". It was observed that "...all children were put to bed, either for the night or for a nap, with a nursing bottle of milk from which they drank, while lying down, to help them fall asleep...". It also stated that "... few parents request a dental examination of children under three years of age...".

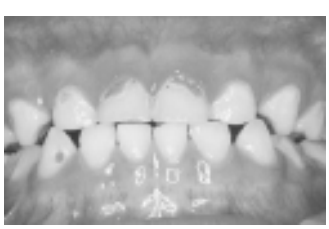
Rampant caries in infants and youngsters has been referred to by various names, including "nursing caries", "nursing bottle syndrome", "night bottle mouth" and "baby bottle tooth decay"; with the inappropriate use of nursing bottle as the perceived central theme. Prolonged use of a nursing bottle, especially during bedtime is believed to be associated with increased risk of caries. However, the nursing bottle is not the only the factor in caries development. Since 1994, the Center for Disease Control and Prevention (CDC) recommended using the term "early childhood caries" (ECC) to describe any form of caries in infants and preschool children. This term was chosen because it better reflects the multi-factorial etiology processes of this disease. Even the parent's parenting style should be considered (Everdingen et al 1996).

A comprehensive review of the epidemiology of caries in primary maxillary anterior teeth showed that the prevalence was from 1% to 12% in developed countries and as high as 80% in developing countries in Africa and south Asia (Milnes 1996).

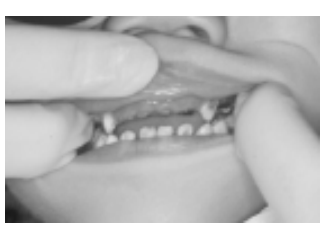
The first sign of dental caries, is the appearance of whitish demineralized areas in the cervical region of the maxillary anterior teeth (Steiner et al 1992, Lith & Grondal 1992). The parent may not detect this demineralization (Ripa 1978) and incipient lesions may progress to cavitation within 6 to 12 months (Weinstein et al 1994). It was reported that 64% of incipient lesions detected at the age of 2.5 years progressed to cavity after one year (Grindefjord et al 1995). In an advanced stage, the crowns of all the maxillary incisors may become totally destroyed, leaving only the root stumps.

Teeth are affected in the order in which they erupt and consequently the maxillary incisors are the first and most severely affected teeth (Derkson et al 1982). Mandibular primary molars become affected because of the repeated pooling or stagnation of cariogenic substrate. The condition has also been reported in those children who have a history of sucking a pacifier dipped in a sweetener and in children who have practiced prolonged at-will feeding (Kotlow 1977).

The treatment of ECC is difficult, time consuming, demanding and also expensive. Treatment includes restoration, pulp therapy, extraction of caries teeth. Extraction of teeth may be needed. Untreated primary teeth with active caries will progress to abscess formation. The spread of infection down the alveolar bone will affect the tooth germ development of the permanent successor. The dental team and parents must be united (Brice et al 1996) for prevention and education to produce a happy and healthy child both physically and psychologically.



Demineralized areas in the cervical region



Total destruction of crowns of all four maxillary incisors

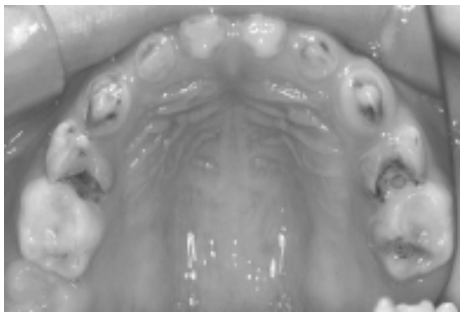


Figure 1a

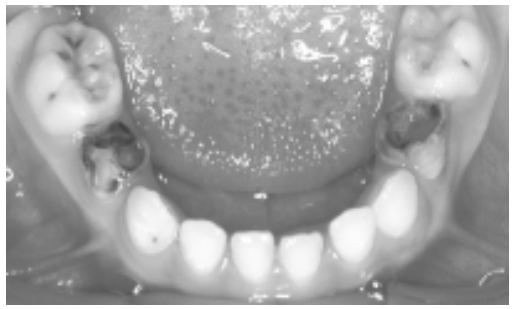
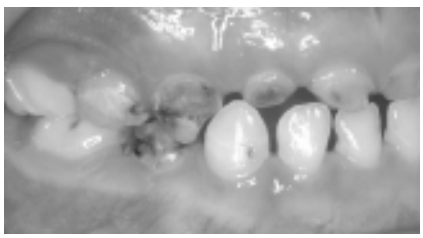


Figure 1b



Fibure 2a

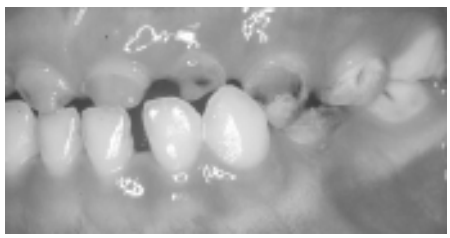
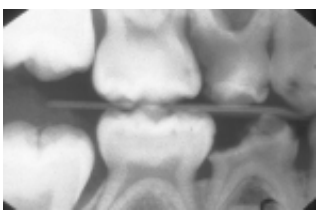
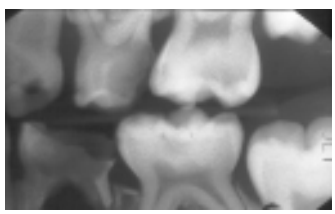


Figure 2b



Right Bitewing radiograph



Light Bitewing radiograph

Pre-treatment

Post-treatment

The bacteria, Streptococci mutans (MS) in the oral cavity which have many cariogenic characteristics (Milnes & Bowden 1985) one of which is the ability to fermentate dietary carbohydrates to produce acid. The drop in pH in the plaque produces acid which leads to demineralization of enamel. It is well known that sucrose, the most commonly available sugar, causes caries (Gustafsson et al 1954, Newburn 1989). The sites at which clearance of carbohydrate is slowest explains in part the distribution of carious lesions in ECC; that is, the labial surfaces of the maxillary incisors and the buccal surfaces of the mandibular molars (Hanaki et al 1993). Hence, carious maxillary primary incisors and first molars are the characteristics of ECC (Ripa 1988, Milnes 1996). Caries in primary dentition leads to higher caries risk in permanent dentition (Kaste et al 1992).

Differences in sugar consumption (King 1978), oral hygiene habits (Alaluusua & Malmivirta 1994) and maternal levels of MS (Berkowitz et al 1981) may lead

to different initial acquisition rates of MS. Maternal saliva with high concentration of MS were associated with a higher infection rate of the infant compared those children of mothers who had low concentration of MS (Berkowitz et al 1981). It was reported that MS constituted less than 1% of oral flora in children with a low caries experience, while it constituted between 30% to 50% of oral flora in individuals with ECC (Berkowitz et al 1984).

Milk was suggested to have the ability to decrease the solubility of enamel (Jenkins & Ferguson 1966). It is possible that the milk exerts a protective effect, by increasing the calcium and phosphate concentration in the plaque and by raising the buffering capacity through peptide catabolism (Reynolds 1987). Soy protein based infant formula milks are naturally lactose free but may contain added fermentable carbohydrate and sucrose. The sweetener in formula milks vary, some contain sucrose, others may have corn syrup and lactose. In general, milk without added substrates is beneficial to dental and general health.

It is well recognized that liquids containing sucrose, especially those in a nursing bottle are cariogenic. Children who consumed beverages containing sucrose from a nursing bottle had levels of Streptococci mutans (MS) that were four times higher than in those who consumed milk from a nursing bottle (Mohan et al 1998).

The excessive consumption of fruit juice and soft drinks can cause enamel loss in children (Frostell 1970, Smith & Shaw 1987). Even natural fruit juices contain a significant quantity of sugars and so their improper use in a nursing bottle can lead to dental caries (Powell 1976). When fruit-based drinks are consumed using a straw, the pH drop in the oral cavity is less pronounced than drinking conventionally (Tahmassebi & Duggal 1997). Hence, the possibility of other dietary practices, besides using nursing bottle leading to demineralization of the teeth cannot be ignored.

Developmental enamel defects in the primary dentition may be due to one of the many hereditary, ante-natal, peri-natal or post-natal factors that cause a systemic or localized disturbance to amelogenesis. Premature birth, low birth weight, malnutrition, metabolic disorders and chemical toxicity are some examples of these factors that can result in developmental defects of enamel (Seow 1991). Surface irregularities predispose to plaque accumulation and thus, the colonization of MS (Li et al 1994), and probably decreased rates of carbohydrate clearance.

The source of carbohydrates in infants may be sugars in milk, non-dairy based drinks and solid foods (Ripa 1988, Milnes 1996). Raw starch causes only a minimal drop in pH (Mormann & Muklemann 1981). However bread and biscuits which contain soluble and refined starch can cause a variable pH fall that is comparable to that of sugars (Firestone et al 1984). In addition, there may be a combination of starch and sugar during food production.

There is no doubt that an increase in frequency of sucrose intake will increases the acidity of the plaque, and the establishment of MS (van Houte et al 1994). The prolonged presence of sugar in the oral cavity increases the potential for enamel demineralization, and leaves inadequate time for remineralization by saliva (Loesche 1986). Children with ECC can be expected to have a high frequency of sugar consumption in the form of fluids from a nursing bottle (Holt et al 1982) and of sweetened solid foods (Gordon & Reddy 1985).

Saliva is the main mechanism for clearing foods and bacteria from the oral cavity. Acids may be neutralized by salivary buffers (Dawes 1984). Saliva is also the reservoir of calcium and phosphates for remineralization of enamel (Dawes 1984) and antibacterial factors which are derived from specific and non-specific immune factors (Twetman et al 1981, Tenovue et al 1987). The reduced flow rate and change in viscosity of saliva during sleep decreases the oral clearance of carbohydrates and hence increases the length of time between plaque, enamel and substrates will explained the increased cariogenicity of the substrates (Firestone 1982). It was found that there was a statistically significant greater incidence of nursing caries in children who fell asleep with the contents of the bottle unfinished than those who finished the contents or discarded the bottle before falling asleep (Schwartz et al 1993).

It was reported that by the age of one year, more children with caries continue the use a nursing bottle (Weinstein et al 1992, Febres et al 1997). The introduction of semi-

solid food should commence at the age of 4 to 6 months old and be accompanied by a gradual decrease in breast and bottle feeding (Fanning 1985).

Chronically sick children have often had to take sugar-based medicines on a regular or frequent basis (Roberts & Roberts 1979). The administrations of sweetened medications in nursing bottles may become one of the causes of caries for young sick children. Furthermore, it can be seen that chronically sick children have an increased risk of caries development because of a predisposition to enamel hypoplasia (Seow 1991, Pascoe & Seow 1994) and a higher likelihood of being comforted by means of a bottle containing a sweet fluid and the frequent exposure to sweetened medications (Feigal & Jensen 1982, Hallett et al 1992). It may not be the illness itself but the parental reaction towards the illness that leads to the greater consumption of sugary food between meals (Winter et al 1971).

Although caries occurs initially on surfaces which can be easily assessed by routine toothbrushing, poor oral hygiene is a major risk factor for caries (Eronat & Eden 1992). Nevertheless, visible plaque on the labial surfaces of the maxillary incisors was found to be a good indicator for future caries risk in 1.5 years old children (Alaluusua & Malmivirta 1994).

It was found that habit established by the age of one year can be expected to be maintained throughout early childhood (Wendt 1995), and lead to a lower prevalence of caries (Silver 1974). It is important to start good dietary habits and oral hygiene early. Although toothbrushing is widespread and well accepted there is variation in when and how the behavior should be practiced by very young children (Blinkhorn 1981). Several studies have shown that increased toothbrushing frequency and parental involvement can decrease the prevalence of carious lesions on smooth surfaces (Winter et al 1971, Schroder & Granath 1983, Persson et al 1985, Paunio et al 1993, Wendt et al 1994).

In 1992 the Department of Health (Annual Report 1993) conducted a survey on children from 3 to 6 years old. The mean untreated decayed, missing and filled primary teeth was 1.1 to 1.9. At the age of 5 years, the percentage of caries free children was 54%. It was found that almost all carious teeth were untreated and 16% of the children had more than 3 untreated carious primary teeth. International reports over the last decade have indicated that dental caries is becoming less of a problem in child populations (Holm 1990). However, Chinese pre-school population do not seem to fit the pattern as in more developed countries (Hu & Liu 1992, Douglass 1994).

A local survey in 1998 on caries prevalence, feeding habit, oral hygiene habits and dental attendance patterns of preschool children revealed that caries prevalence in the age group of 31 to 44 months was 20 percent. The maxillary central incisors were most affected. 14.5 percent in the caries group had more than six carious teeth. Only 3.2 percent of caries teeth had been restored.

It was found that 63.7 percent of children used nursing bottle at bedtime. 19.5 percent of dentate subjects were found to have poor oral hygiene. Favorable oral hygiene habits, toothbrushing, was performed by 42.3 percent of the children. Of these, more than half were left to brush on their own. 44 percent of the children who brush the teeth manage to perform the brushing once a day. 26.4 percent of caregivers did not know the oral condition of their children. Most caregivers visited dentists irregularly while 25 percent of caregivers had regular dental checkup. The utilization of dental services by pre-school children was found to be low; 98.5% of children aged 3 had never been to a dentist.

Early childhood caries is a social, political, medical, dental and behavioral problem which can only be controlled through a thorough understanding of the dynamics of the society, the family structure, methods of nurturing children and socio-economic factors.

As the dietary habits, oral health habits and dental attendance patterns of pre-school children are controlled by parents, they should be recommended:

1. To start good home care; especially dietary and oral hygiene habit early.
2. To start weaning early and to feed with a cup instead of bottle as the child grows.
3. To reduce the frequency of snacking as well as supply of sweeten food.
4. To assist the children to brush the teeth twice a day.
5. To use child toothpaste, the size of a pea to brush the child's teeth when the child can spit out.
6. To have the first dental check up for the children by the age of three years old.