

Gas chromatography-mass spectroscopy analysis of emissions from cement when using ultrasonically driven tools

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Background Ultrasonically driven tools have been used to reduce the incidence of complications during cement removal at revision hip replacement operations. These have been shown to be safe and effective in various ways, but produce fumes.

Methods Using gas chromatography-mass spectroscopy, we analyzed the fumes produced during the use of these ultrasonic tools for the removal of bone cement, both in the laboratory and during actual surgery.

Results Benzene, styrene, methylmethacrylate, xylene, toluene, isopropyl alcohol and dichlorobenzene were some of the substances isolated from the fumes in the laboratory. Styrene and methylmethacrylate were the main components. Concentrations of all the above components taken from the breathing zone of the operating staff during actual surgery were well below the safety limits.

Interpretation The use of ultrasonic tools for cement removal appears to be safe.

Ultrasonically driven tools have been used to reduce the incidence of cortical perforations and femoral fractures during revision arthroplasty.

Using gas chromatography-mass spectroscopy (GC-MS), we analyzed the fumes produced during the use of these tools for cement removal in a laboratory setting and from the breathing zone of a surgical team during a revision total hip replacement operation involving cement removal.

We aimed to address the health and safety issues regarding exposure of the surgical team to these substances.

Definitions and occupational exposure limits

Under the Control of Substances Hazardous to Health regulations (COSHH, 1999), there are 2 types of occupational exposure limits (OEL)—namely maximum exposure limits (MEL) and occupational exposure standards (OES).

Both types of limits refer to concentrations of the hazardous substances in air, averaged over a specified time period referred to as a TWA (time-weighted average). Two periods are used, long-term measurement (8 h) and short-term measurement (15 min).

MEL (maximum exposure limit): the maximum concentration of an airborne substance, averaged over a reference period, to which employees may be exposed by inhalation under any circumstances. For substances assigned a short-term MEL (15 min reference period), the MEL should never be exceeded (EH-40 2002).

■ MEL is set for substances which may cause the most serious damage to health, such as cancer and occupational asthma, and for which 'safe' levels of exposure cannot be determined. A MEL is also set for substances for which the levels cannot be controlled practicably—although safe levels may exist.

OES (occupational exposure standards): the concentration of an airborne substance, averaged over a reference period, at which—according to current knowledge—there is no evidence that it is likely to be injurious to employees if they are exposed by inhalation, day after day (EH-40 2002).

Material and methods

The ultrasonic equipment used was the Orthosonics System for Cemented Arthroplasty Revisions (OSCAR; Orthosonics Ltd., Ashburton, Devon, UK). Ultrasonically driven tools such as the OSCAR system have an ultrasonic console which converts electrical energy into mechanical energy, which is then applied through a variety of probes. This produces heat to liquify the cement, thus facilitating removal (Cailloutte et al. 1991, Gardiner et al. 1993).

Part A

We used 4 commonly used cements, namely: 1. Palacos without gentamicin; 2. Palacos with gentamicin (Schering-Plough Ltd., Brussels, Belgium); 3. CMW (Depuy International, Blackpool, UK); and 4. Simplex with erythromycin (Howmedica, Limerick, Ireland). All the cements were mixed and set in a theater environment using the Depuy SEMVAC system. The cements were allowed to cure in the plastic syringe tubes. Before the cements set, a central channel was created using a hip prosthesis stem. This was done to allow us to insert the probe of the ultrasonic tool. The tubes were mounted on to a laboratory clamp stand.

A serial air sampling train consisting of a filter backed up with a Tenax adsorbant glass tube (SKC Ltd., Blandford, Devon, UK) was used to collect the air samples. A low-flow personal sampler (i.e. pump) was used to draw air through the sampling chain at a flow rate of 200 mL/min. This allowed collection of the aerosols on the filter and the vapor fractions of the fumes onto the Tenax tubes.

We applied the OSCAR probe in the standard fashion to the cement, to produce a plume, during which the low-flow sampler was drawing air for a fixed time of 2 min. This was repeated twice for each type of cement. This gave us 2 filters and Tenax tubes for each of the 4 cement types. These were labeled, sealed and analyzed using GC-MS at the Institute of Occupational Medicine, Edinburgh, U.K.

Part B

During a standard revision total hip replacement operation, we used a serial air sampling train (consisting of a filter backed up with a Tenax tube) to

Comparison of concentrations of major components determined from GC-MS analysis of the two Tenax tubes from each sample with OES and MEL values (Part A)

OES ^a , MEL ^b and cement sample	Methyl methacrylate mg/m ³		Styrene mg/m ³	
8-hr TWA ^c	208	OES ^a	430	MEL ^b
15-min TWA ^c	416	OES ^a	1080	MEL ^b
Palacos				
without gentamycin	943	893	63	26
with gentamycin	914	742	22	61
CMW	741	799	41	< 1.2
Simplex with erythromycin	879	746	48	154

^a OES occupational exposure standards,

^b MEL maximum exposure limits,

^c TWA time-weighted average

collect the air samples from the breathing zone of the surgeon, assistant, scrub nurse and anesthetist, each of whom was equipped with the pump. The filter was brought out from under the surgical gown and fixed near the lapel, i.e. within 20–30 cm of the person's nose and mouth (breathing zone). The surgical suction machine was switched off during the time that OSCAR was being used. The time duration for which the pumps were switched on was noted.

Results

Part A

The minor components identified on analysis were benzene, xylene, toluene, isopropyl alcohol, dichloromethane, dichlorobenzene and acetone. In addition, methylmethacrylate and styrene were the most predominant compounds in the fume samples. The Table gives the concentrations of these components obtained on GC-MS analysis of the tenax tubes, and these are compared with the occupational exposure standards (OES) and maximum exposure limits (MEL).

Part B

The concentrations of the various substances, including methylmethacrylate and styrene, in the breathing zone of the surgical staff were between 0.01 and 0.24 mg/m³.

Discussion

The main components obtained from the Tenax tubes were methylmethacrylate and styrene. Methylmethacrylate, styrene and other compounds are probably thermal degradation products from the cements. These two components are considered in detail below.

Styrene

The current recommendations (MEL) are 430 mg/m³ (8-hr TWA) and 1,080 mg/m³ (15-min reference period) (EH-40 2002, EH-64 1983, Toxicity review TR1 1981).

Styrene is a respiratory irritant. Exposure levels of 430 mg/m³ have been shown to have effects on the central nervous system such as tiredness and drowsiness. Performance in psychomotor tests has been shown to be impaired at 1,505 mg/m³, and thus the short-term MEL was set at 1,080 mg/m³ (15-min reference period). Workers exposed to styrene levels of 322 mg/m³ with excursions above 430 mg/m³ have experienced an increased incidence of chromosomal abnormalities in leukocytes. Such effects were not seen in workers at low levels. From the limited number of mortality studies, however, there has been no evidence to suggest that styrene is carcinogenic (EH-64 1983, Toxicity review TR1 1981).

Methylmethacrylate

This compound is highly inflammable and an irritant to the eyes, the skin and the respiratory system. It is a potential skin sensitiser. The current recommended (OES) is 208 mg/m³ (8-hr TWA) and 416 mg/m³ (15-min reference period) (EH-64 1994).

A limited number of case reports of asthma have been observed where exposure to methylmethacrylate was characterized by high peak levels over a short duration (i.e. approx 1,555 mg/m³ in less than 1 min) (Pickering et al. 1986).

It is evident that the concentrations of methylmethacrylate in the plume samples are much higher than the occupational exposure standards. However, the relevance of this finding for surgical practice can only be ascertained from the concentrations in the breathing zone of the surgical staff. Although peak concentrations of 1,555 mg/m³ have been recorded in medical and dental applications,

short-term personal TWA exposures are likely to be less than 416 mg/m³. Also, methylmethacrylate is metabolized extensively and rapidly with a half life of approximately 1 h (EH-64 1994).

The concentrations of all the components in the breathing zone of the surgical staff were extremely low compared to the OES/MEL.

Other factors should be considered regarding the use of ultrasonic tools. The use of these tools by the surgical team is an infrequent event—occurring perhaps once or twice a week. Surgical masks are worn universally and suction systems are in use during the process of cement removal. Some centers also use body suits during arthroplasty procedures. Surgeons usually use ultrasonic tools to complement their mechanical method of cement removal. Thus, the use of these tools is infrequent and relatively limited for each individual.

Ultrasonically driven tools have been shown to be safe with regard to the thermal effects and histological changes at the endosteal surface of the bone (Cailloutte et al. 1991a, b). They have also been effective in reducing the operating time, and the incidence of perforations and fractures (Gardiner et al. 1993). They also help to preserve bone stock (Fletcher et al. 2000).

We thus conclude that the fumes produced during the use of ultrasonically driven tools for cement removal are safe to surgical staff.

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No competing interests declared.

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