A Literature Review to Determine if Diathermy Smoke is Hazardous to Health

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Abstract

The heat used in electro cautery causes cells to boil and explode or simply dry producing a gaseous by product known as diathermy smoke, this smoke may have mutagenic and carcinogenic potential similar to that of cigarette smoke. (Spearman et al 2007)

A search of electronic databases was performed and selected articles were reviewed using the Critical Appraisal Skills Programme (CASP) tool to enable a review of relevant articles to be undertaken.
The findings of the review were that 45 compounds were identified 9 of these were found to be hazardous when cross referenced against the Control of Substances Hazardous to Health (COSHH) list of approved workplace exposure limits and 4 were carcinogens;

This research indicates that the use of an extraction device to remove smoke when using diathermy is best practice. However, until more conclusive evidence is available on the actual health risks of diathermy smoke as opposed to the potential health risks, it will be difficult for the organisations that govern health and safety at work to create legislation on the need to extract it from the operating theatre air.

Introduction

The history of diathermy dates back to the late 19th century when Thompson developed a generator capable of producing a high frequency current, noticing heat in his wrists when current was passed through his hands immersed in saline (Pollack et al 2000). The Health and Safety Executive (2012) indicated in their evidence based literature review that methods used to dissect tissue and stem blood flow during surgery have changed as technology has developed. Electro-surgery have

become commonplace, so that medical staff in the operating theatre are (potentially) increasingly exposed to the thermal decomposition products of tissues.

Depending on the nature of the surgical site and the length of the procedure, staff (especially the surgeons and scrubbed team) can be exposed to smoke. This is most manifest in how obnoxious the smell is.

Diathermy Smoke

Concerns have been expressed about the components of diathermy smoke HSE (2012) COSSH (2006), which contains 95% water and 5% cellular debris (Ulmer 2008). The 5% cellular debris is thought to be composed of a magnitude of different chemicals, some of which may have mutagenic and carcinogenic potential similar to that of cigarette smoke (Ortolano et al 2009). Alp et al (2006) believe the mutagenic effect of the ablation of 1 gram of tissue is comparable to that of 6 cigarettes. Despite growing concerns about the potential hazards of diathermy smoke there are no clear guidelines on diathermy smoke.

Review of literature

This review of the literature was undertaken to explore existing information regarding the subject area. It was undertaken as part of a University module exploring advancing perioperative practice. In order to identify useful key words Traditi (2003) encourages the use of the 'PICO' framework, which looks at what the question is asking from four perspectives: -

Patient or problem – diathermy smoke
Intervention – chemical composition
Comparison intervention – evacuation versus no evacuation
Outcome – reducing hazard

From this 'diathermy' was used as a starting point, resulting in 6,717 articles being found. This being an overwhelming number of articles for a study of this size the search was refined with the introduction of a Boolean operator and a second term.

Using the key words ‘diathermy’ AND ‘smoke’ a more focussed search was achieved resulting in 171 articles being found.

By limiting the search to scholarly articles within the last 8 years relating to surgery, the search was narrowed to 53 articles, from which 5 articles were chosen. Alternative key words of ‘electrocautery’ AND ‘smoke’ and ‘smoke’ AND ‘operating theatres’ were used, resulting in 308 articles where 1 of these was chosen and 492 articles where 2 further articles where chosen.

The CASP tool was used to extract relevant information from the articles regarding the validity and reliability of the studies, which relates greatly to the methodology sections of the articles. All of the studies provided a detailed methodology Botti and Endacott (2005) state that one of the fundamental principles of quantitative data collection is empiricism. Providing a detailed description of the data collection process ensures that others can replicate observation and measurement.

What compounds are present in diathermy smoke and are they hazardous to health?

The results listing the compounds found in the articles reviewed were compiled into a table (table 1) to determine which compounds were present in diathermy smoke, 45 compounds identified in total. Using the COSHH list of approved workplace exposure limits as defined by the Health and Safety Executive (HSE) (2007), those compounds found to be hazardous to health were identified (table 2).

Table 2 shows that all of the compounds found in multiple studies were identified during different surgical procedures, which infers that these compounds may be present in all surgical procedures, although the concentration of each compound varies depending on the surgical procedure.

The COSHH list of approved workplace exposure limits (HSE 2007), provides guidance of both the long and short term permitted exposure limits (PEL) for all given hazardous substances using milligrams per cubic meter (mg.m3) and parts per

million (ppm) as the measurement units. The results found in the studies were converted into mean amounts where a mean was not provided and also into either mg.m3 or ppm. Using the COSHH long-term exposure limits the results were then compared to the PEL, shown in table 2. Moot et al (2007) was the only study to find a compound that was over the PEL this was from the sample taken direct from the tip of the diathermy pencil. Hydrogen Cyanide was found in a quantity of 16.3 ppm the limit being 5 ppm. Moot et al (2007) also collected samples from the level of the surgeons' headlight, the level being 0.053ppm, which is within the PEL for hydrogen cyanide. None of the other studies exceeded the PEL for any of the compounds found.

The list of symbols, abbreviations, risk and safety phrases issued by the HSE (2009) was used as a guide to identify in what way the compounds found in the studies are hazardous to health.

Acrylonitrile - This compound is of great concern as it has been identified as a substance that may cause cancer. It is also known to be irritating to the respiratory system and skin and is toxic if inhaled. There may also be risk of serious damage to eyes.

Benzene – This is a potentially cancerous substance. Ulmer (2008) suggests that it may cause bone marrow damage and injury to the tissues that form blood when subjected to chronic low-level exposure. Benzene is also irritating to eyes and skin, and is toxic if prolonged exposure is experienced; resulting in symptoms such as headache, weakness, appetite loss and fatigue.

1-3 butadiene – The main concern of this compound is that it has been identified as a substance that may cause cancer and has also been linked to heritable genetic damage.

Cyclohexanone – This substance is harmful when inhaled.

Ethylbenzene - This substance is harmful when inhaled.

Formaldehyde – There is some limited evidence that this compound may have a carcinogenic effect. Formaldehyde is toxic when inhaled and can cause burns when in contact with skin.

Hydrogen Cyanide – This substance is known to be toxic by inhalation. Moot et al (2006) also identify that it can cause headache, weakness, altered taste and smell, abdominal colic and deficiency in B12 and folate.

Styrene – This substance is a respiratory irritant and can also be irritating to the eyes and skin.

Toluene – This substance is well absorbed by the respiratory tract and the HSE (2007) warn of danger of serious damage to health by prolonged exposure. Toluene vapours may cause drowsiness and dizziness, can be irritating to skin and there is some risk of harm to unborn children.

What is the most effective management strategy for diathermy smoke?

Pillinger et al (2003) found that when an extractor was used during neck dissection, there was significantly less smoke reaching the level of the surgeons face. This was a difference of 0.12mg/m3, which is 6 times less than when no extractor was used at all. Andreasson et al (2009) found that the size of particles found in diathermy smoke was small enough to reach alveoli in the lungs and move into the cardiovascular system. Particles of this size, referred to as ultrafine particles, can cause inflammatory changes in the respiratory tract, nausea, carcinoma, dermatitis and cardiovascular dysfunction (Andreasson et al 2009). Andreasson et al (2009) also discovered that surgical facemasks do not filter ultrafine particles and as such are not a suitable barrier. Surgical facemasks can filter particles of a size of 5 micrometers (ųm) or more; Andreasson et al (2009) found that ultrafine particles of 0.07ųm were generated with the use of diathermy. Andreasson et al (2009) advise the use of an extractor but found that even the filters on extraction units are not sufficient to cope with ultrafine particles and further developments should be made. Hassan et al (2006) found that further studies were needed using more sophisticated

measuring equipment as well as further development of extraction systems. Al Sahaf et al (2007) advised that staff exposed to surgical smoke should be made aware of the risks but were not specific in what measures should be taken to reduce the risk. Pillinger et al (2003) was the only study to identify a specific type of evacuation tool in the Lina grey Shark, which is a diathermy pencil with an integrated suction unit that does not alter the user's technique during surgical procedures.

The HSE (2012) in a more extensive Systematic review of the literature found that the majority of studies presented quantitative evidence of smoke reduction and control, using extraction devices in order to reduce worker exposure to emissions during activities related to the surgical cutting of tissues. Where these interventions were compared with an absence of smoke control, the interventional extraction typically demonstrated an improvement in air quality, though this was limited and dependent on point of extraction, type of extraction and the type of emission plume assessed (e.g. from laser, electrocautery, ultrasonic methods).

Compounds in diathermy smoke

There were 45 different compounds identified in this review as being present in diathermy smoke. All of these compounds were cross referenced against the COSHH list of approved workplace exposure limits as defined by the HSE (2007) of which 9 were identified as being hazardous to health. Acrylonitrile, benzene, 1-3 butadiene and formaldehyde are all substances that the HSE identify as being carcinogenic, however, the levels of these compounds found present in diathermy smoke within the studies were well below the PEL advised by the HSE (2007). Chung et al (2010) discuss two occupational health studies of rubber industry workers, who experience long-term exposure to low levels of 1-3 butadiene, which reports health problems such as heart, blood and lung disease and leukaemia. Although toluene is not identified as a carcinogen by the HSE (2007), danger warnings are given of serious damage to health by prolonged exposure. Lin et al (2010) found that the toluene produced during a single breast surgery exceeded that produced by smoking a pack of cigarettes. The Agency for Toxic Substance and Disease Registry (ATSDR) is directed by congressional mandate in the United States to help protect the public health from hazard in the environment. The ATSDR give minimal risk levels for chronic exposure to certain chemicals and compounds,

the amount for chronic exposure to toluene is 0.3mg/m3 or 0.08ppm (ATSDR 2009). When comparing the study by Lin et al (2010) to the ATSDR, chronic exposure for toluene exceeds the minimum risk level, which can cause neurotoxic effects and impair colour vision (Lin et al 2010). 1-3 Butadiene and toluene have been recognised as compounds that cause damage with prolonged exposure by the articles mentioned above, in addition, benzene is recognised by the HSE (2007) as having similar health risks with prolonged exposure. Although the levels found over all for all the compounds identified did not exceed the PEL it could be possible that no studies have been undertaken to find the possible health risks with prolonged exposure. Hassan et al (2006) agree with this by stating that *'although the authors were unable to detect measurable levels of any of the toxic or mutagenic components of electro cautery smoke, they do exist and, therefore, the cumulative exposure of even minute un-measurable amounts over a surgeons lifetime may not be insignificant'* (pg 41).

Many of the articles collected the samples of diathermy smoke from close to the tip of the diathermy pencil, which may not give a good indication of the exposure of the surgeon. Lin et al (2010) describe how laminar flow ventilation, present in all theatres, may dilute the concentration of diathermy smoke. Andreasson et al (2009), Pillinger et al (2003) and Hassan et al (2006) were the only studies to collect samples from the level of the surgeons face, Hassan et al (2006) indicates that this is important, as it is representative of the surgeons' actual exposure.

Hassan et al (2006) states that it is routine to wear protective facemasks in the United States based on standard guidelines by the OSHA and other regulatory agencies. Barrett and Garber (2003) suggest that surgical facemasks have not been shown to provide adequate protection from diathermy smoke and that they cannot protect against particles smaller than 5 ųm. Andreasson et al (2009) found that ultrafine particles of 0.07ųm were generated with the use of diathermy and state that even if facemasks were made more effective the user would find it difficult to breathe.

Pillinger et al (2003) identify two different methods for extracting diathermy plume. The first method involves simply holding a suction device near to the diathermy

pencil tip, which is reliant on the experience of the assistant and uses up one of their hands. The preferred method was the use of an integrated diathermy pencil and smoke extraction system, which operates the same as a normal diathermy pencil and would require little change to operating technique. Spearman et al (2007) found negative attitudes towards such devices amongst surgeons who said that they were too expensive and cumbersome to use. However, the Spearman et al study (2007) was undertaken in excess of 4 years ago and technology has most probably improved since this time.

Lin et al (2010) and Hassan et al (2006) were inconclusive in their findings, they advise that further studies need to be undertaken to ascertain the long term effects of diathermy smoke on those exposed to it. Perhaps what is required is a longitudinal empirical study to identify physiological changes in theatre staff over a significant number of years. Barrett and Garber (2003) illustrate, a study over a long time scale involving a large number of people would be financially challenging and could be construed as ethically unacceptable if deliberately allowing individuals to be exposed to something that is perceived to be hazardous to health. A study that may be more viable on resources could be a study to compare the health of workers who are exposed to diathermy smoke with the health of workers who are not. Bigony (2007) agrees with this and adds that authentic surgical conditions should be used in research rather than laboratory style simulations in order to produce more convincing findings.

The regulatory agencies that govern Health and Safety policy such as the OSHA in the United States and COSHH in the United Kingdom are unable produce policy on the evacuation of diathermy smoke until a study is undertaken that can conclusively determine the realistic long and short term health risks.

Al Sahaf et al (2007) advised that staff exposed to surgical smoke should be made aware of the risks. Various nursing organisations provide guidance on the evacuation of diathermy smoke, The International Federation of Perioperative Nurses (IFPN) and the AORN both provide guidelines on the evacuation of diathermy smoke (IFPN 2011), in addition the AORN have devised a smoke evacuation tool kit as guidance for creating hospital policy (AORN 2011). This being

the case NICE, who provide national guidance to the NHS when formulating policy, have not as yet provided any guidelines regarding diathermy smoke.

Conclusion

Although 45 compounds were identified as being present in diathermy smoke, Nine of which have properties found to be hazardous to health, four of which are carcinogens, none of the compounds found exceeded the PEL's outlined by the HSE (2007). All of the articles were in agreement that diathermy smoke contains compounds that are hazardous to health but are inconclusive about the extent to which individuals are affected by these compounds. Despite there being inconclusive evidence 5 of the articles advise the use of an extractor whenever diathermy is in use.

NIOSH (1998) have provided guidelines for the use of extractors whenever diathermy is in use in the United States despite the OSHA finding that there is not enough evidence to prove it is a health risk. In the United Kingdom organisations such as the Health and Safety Executive or Department of Health have not yet produced definitive guidance in this area.

Recommendations

One of the aims of this review of literature was to evaluate the findings to determine if there is a need to produce a local policy on the evacuation of diathermy smoke. The findings of this study were inconclusive. There was also a lack of precedent set by the organisations that govern health and safety at work such as the HSE, and NICE who provide guidelines on best practice to the NHS. There is not enough supporting evidence that proves that diathermy smoke is hazardous to health, therefore it would not be prudent to produce a local policy on the evacuation of diathermy smoke at this time.

Diathermy smoke does contain compounds that are hazardous to health, albeit in small proportions, therefore the only ethically acceptable solution would be to inform those

who are exposed to diathermy smoke on a daily basis of this potential hazard as recommended by Al Sahaf et al (2007) and to make them aware of the alternatives.

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Table 1 The results listing the compounds found in the articles reviewed .

Propene							✔	
propylbenzene				✔				
propylene	✔							
Styrene						✔	✔	
Tetradecane				✔				
Tetradecene				✔				
Toluene		✔				✔	✔	
Tridecane				✔				
Undecane				✔				
Undecene				✔				
Xylene				✔		✔	✔	

Table 2. Using the COSHH list of approved workplace exposure limits as defined by the Health and Safety Executive (HSE) (2007), those compounds found to be hazardous to health were identified