

# Diathermy smoke shown to be hazardous, so why are we not protecting ourselves?

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## Abstract

Diathermy smoke has been studied for over three decades and data has been collected to establish its composition. Although its full structure has not been established, the compounds confirmed pose a health hazard to all exposed. Recommendations suggest that theatre staff need to protect themselves using smoke evacuating systems and masks. This review looks at the compliance of theatre staff within these guidelines and the reasons behind noncompliance.

## Keywords

Diathermy / Smoke / Compliance / Hazard

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## Introduction and Background

Since the early twentieth century, diathermy units have been used during surgical procedures to facilitate haemostasis and the cutting of tissue (Rothrock & McEwan 2011). During its use, high frequency electrical currents vaporise fine particles and cellular fluid, dispersing them into the air producing a smoke (plume). Diathermy smoke has been studied for over three decades (Sagar et al 1996) and data has been gathered regarding its chemical makeup.

Despite the vast amount of research, the full biological and chemical composition of diathermy smoke cannot be confirmed due to factors such as technique, patient and collection methods. Tregoning (2015) estimated that there are around 150 chemical compounds found in diathermy smoke and Fitzgerald et al (2012) believed that some of the substances found could be carcinogenic (See Figure 1). Additionally Lindsey et al (2015) found that these substances could be mutagenic and possibly be infectious. Toluene, although not considered carcinogenic (HSE 2012), can be neurologically harmful and is present in the smoke. In addition Lin et al (2010) found that the levels of toluene in diathermy smoke were greater than those present in the smoke from a pack of cigarettes.

The compounds confirmed do cause concern for the health of staff being exposed. Lindsey et al (2015) suggested that precautionary measures needed to be taken, which Walczak et al (2011), Mowbray et al (2013)

and Hill et al (2012) agreed should include the use of smoke evacuation systems. The Association for Perioperative Practice (AfPP 2011) and the Health and Safety Executive (HSE 2012) both accept that there are health risks to staff. They have produced guidance/recommendations to educate employers and employees of the hazards and what they can do about it.

The Control of Substances Hazardous to Health (COSHH) guidance suggested that the most effective method of managing diathermy smoke is to use local exhaust ventilation (LEV) to extract the smoke directly from the surgical field. This method of extraction is also commended by the Operating Room Nurses Association of Canada (ORNAC 2011) which stated: 'Whenever electrosurgery is used, it should be used in conjunction with a smoke evacuator' (p 226). The International Federation of Perioperative Nurses (IFPN 2015) outlined the importance of policies demonstrating the risks of diathermy and what practitioners can do to reduce the exposure hazard. However, the Medicines and Healthcare Products Regulatory Agency (MHRA 2011) argued that more studies are needed to observe exposure and its ill-health effects as there is no

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Acetonitrile furfural	Indole
Acetylene hexadecanoic acid	Isobutene
Acroloin hydrogen cyanide	Methane
Acrylonitrile indole	3-Methyl butenal
Alkyl benzene isobutene	2-Methyl furan
Benzaldehyde methane	6-Methyl indole
Benzene 3-methyl butenal	4-Methyl phenol
Butadiene 4-methyl phenol	2-Methyl propanol
3-Butenenitrile methyl pyrazine	Methyl pyrazine
Carbon monoxide phenol	Phenol
Creosol propene	Polyaromatic
1-Decene	Hydrocarbons
2,3-Dihydro indene pyridine	Propene
Ethane pyrrole	Propylene
Ethylene toluene	2-Propylene nitrile
Ethylene 1-undecene	Pyridine
Ethyl benzene xylene	Pyrrole
Formaldehyde	Styrene
Furfural	Toluene
Hexadecanoic acid	1-Undecene
Hydrogen cyanide	Xylene

**Figure 1** Compounds found in diathermy plume (taken from Tregoning 2015)

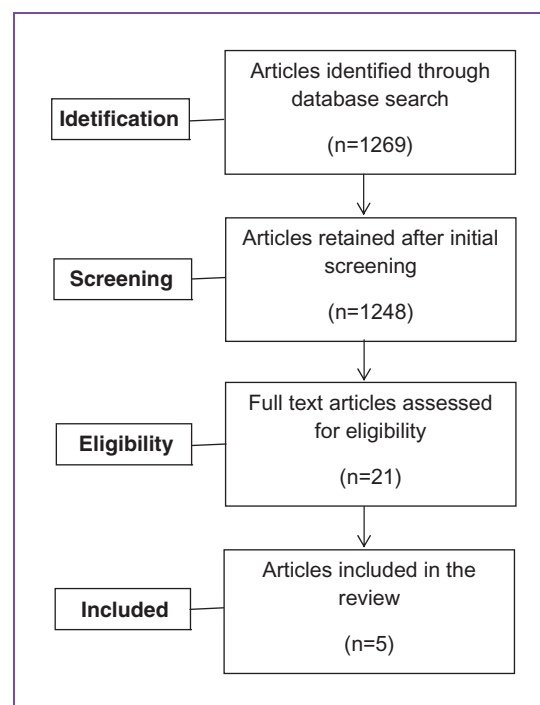
validated evidence to prove or disprove claims. Even though there is no concrete evidence, the HSE (2012) advised that any exposure to smoke should be avoided.

## Search strategy

In order to create an efficient search of the databases the acronym PICO was used. This system is commended by Bettany-Salnikov (2012) and Aveyard (2014) due to its ability to identify key concepts in the research question which aids the development of search terms and keywords. PICO stands for:

- Population – Theatre staff
- Intervention – Diathermy smoke
- Comparison – Compliance
- Outcome – Occupational hazard

To create a structured search strategy, the initial key words were amended using their synonyms (Bell 2010). These included: perioperative, operating theatre, plume, electrocautery, fumes electrosurgical, hazard and risk. In addition, specific inclusion criteria were established using Oliver (2012) and Bell's (2010) recommendations, using only research written in English, within the last five years and expanding only if the data found is not appropriate.



**Figure 2** Summary of search process

Using a variety of databases (Google Scholar, Summon, PubMed, Scopus, CINAHL) data was searched between 2011 and 2016. However, this did not provide enough data so the search was widened to between 2006 and 2016. To ensure full saturation of search terms, Boolean operators were used to help narrow the searches to establish articles that were suitable and included the required keywords (Oliver 2012).

Further analysis was conducted to ensure the literature found was appropriate to this review; each abstract section was analysed ensuring direct relevance to the search question and inclusion criteria. Of the articles found only five were accepted into the review (see Figure 2). They were analysed on the grounds of their validity, reliability, sample, results, analysis of results, methodology and ethics.

## Barriers to compliance

### *Refusal to use the equipment*

Of the five papers analysed for review, three concluded that one barrier to compliance was the surgeons' refusal to use the equipment. Spearman et al (2007) found this to be a significant problem; surgeons rejected smoke evacuation equipment because they found it cumbersome. This attitude was also found by Okoshi et al (2015), who discovered that the surgeons in their review found smoke evacuation devices bulky and awkward to use. Two papers learned that the equipment impacted on the surgeon's dexterity (Sanderson 2012, Ball 2010). Ball (2010) found that surgeon refusal was

additionally due to the noise that the machines created when in use, which impacted on their concentration.

### *Lack of knowledge*

Not only is surgeon noncompliance a result of equipment problems but also this review found that surgeon and theatre staff lack of knowledge about diathermy smoke hazards and preventative measures was also a considerable problem. This review found three of the five studies acknowledge this concern: Ball (2010) found that noncompliance with safety measures was ultimately due to the absence of knowledge.

Spearman et al (2007) studied staff attitudes towards diathermy smoke and concluded that surgeons' comprehension of the dangers was limited which impacted on their use of equipment. Only 51% of consultants believed that it was harmful, in comparison to 91% of nurses. For those surgeons who did use these extraction devices, the rationale was particularly interesting. Of 37 consultant responses, 73% used extractors to improve their view, 57% for their safety and 16% because of the smell produced. These results suggested that surgeons do not fully believe diathermy smoke to be hazardous due to the higher percentage extracting to improve their view.

Stegge et al (2014) suggested that staff in their study were either complacent or needed further education; 68% of 3818 hospital staff exposed to surgical smoke were not aware of or had no procedures in place to minimise the risk to staff health. This result was a surprise; the researchers expected more respondents to have some knowledge of procedure due to exposure guidelines being available.

### **How can compliance be improved?**

#### *Education*

To improve compliance Spearman et al (2007) suggested that staff should have an awareness of the hazards; two of the studies reviewed methods that could help to develop this. Ball (2010) suggested that education and training about the hazards could be improved by organising multidisciplinary meetings, including representatives from companies who supply smoke evacuation systems. Team strategies can be discussed and procedures can be developed to promote use of smoke evacuators. It was suggested that allowing company representatives to give demonstrations improved staff compliance, because staff could experience the ease of setup and extraction in their own time outside the pressures of theatre.

Ball (2010) also suggested providing testimonials of colleagues from other trusts to explain about perioperative environment improvements and how

diathermy smoke has affected them eg respiratory problems. The multidisciplinary team may be able to relate to these staff members and learn about health implications and how they can improve the theatre environment.

Alternatively, Oskoshi et al (2015) suggested that surgeons should assess the potential dangers of smoke and educate staff about these dangers. However, Ball (2010) suggested that nurses should be the main educator. She found that when nurses received education and training about diathermy smoke, the compliance with smoke evacuation recommendations increased. Education for surgeons is suggested to be done by the nursing leaders as they usually have positive relationships with surgeons and can provide appropriate evidence with references to validate their argument. Utilising interconnectedness as an instrument between nurses and surgeons, plans can be compiled and decisions communicated to promote the use of smoke evacuation during procedures. Ball (2010) found that this type of communication improved compliance as staff and surgeons were in agreement and collaborated on their decisions.

### **What precautionary measures need to be used?**

Precautionary measures are demonstrated in all five studies reviewed. Two of these studies recommended surgical masks to be used by staff to reduce their exposure risk. Sanderson (2012) found high filtration masks to be an affective precautionary measure when being exposed. However, Oskoshi et al (2015) criticised the use of standard masks for this type of exposure as they did not protect staff against airborne particles. They found that, even though staff wore masks, they often were not worn correctly and therefore allowed smoke particles to be inhaled. Specific high filtration masks should be made available which offer better protection; however, staff found these hard to breathe in, which makes them very unpopular. Even though masks are a good precautionary measure when used correctly, Oskoshi et al (2015) stressed that they should not be used solely on their own to protect staff, they should be used alongside the smoke evacuation systems. Sanderson (2012) and Ball (2010) concurred, adding that the only reliable method of protection is by using smoke evacuation systems.

### **Discussion**

Within the perioperative environment, theatre practitioners constantly work to ensure that the care patients receive is supported by evidence based practice. It is part of their codes of conduct, either with the Nursing and Midwifery Council (NMC 2015) or the Health and Care Professions Council (HCPC 2014). Both of these codes summarise that patient safety is

paramount. However, staff safety is also important and staff need to ensure that they are safe, taking the necessary precautions towards hazards.

Diathermy smoke is a hazard; there is compelling evidence to support this claim (Rimmer 2009, Hill et al 2012, Mowbray et al 2013), although just how hazardous is still not known (Dunn & Brown 2013). Due to this, Hill et al (2012) believed that further evidence needs to be established to find out the realistic long and short term risk that diathermy exposure poses to theatre staff and patients. Despite this, the MHRA (2008) has recognised that there is a risk to health to all staff exposed to diathermy smoke. The Association of periOperative Registered Nurses (AORN 2012) agreed and published recommended practices to give guidance to practitioners in regards to the health risks and preventative measures. The AfPP (2009) also created guidance explaining that smoke evacuation systems are the only effective method of removing diathermy smoke. This view is concurred by Lindsay et al (2015) who stated that evacuation should be the first line of defence and masks should be secondary.

### *Applying the knowledge*

From the literature reviewed it has become apparent that even though policies have been produced, staff knowledge and implementation is criticised. The literature has shown that theatre staff are unsure or question the potential health risks. Schultz (2014) found this same scepticism and confusion in his study but he suggested this was just due to lack of knowledge. He agreed with the literature review results: theatre staff need education about the harmful effects of diathermy smoke and how to prevent exposure. Dunn and Brown (2013) concurred that, due to the potential risk, the only ethically acceptable solution is to make staff aware so they can be made conscious of its true nature.

### *The need for further evidence*

Despite this, Edwards and Reiman (2008) found that some surgeons still do not consider surgical smoke to be a hazard because there is no validated evidence to support this. This collective view is shared also by government organisations such as the Occupational Safety and Health Administration (OSHA 2011) who argued there is not enough evidence to prove diathermy smoke to be a health risk.

The need for full empirical evidence is what focuses further research. Due to the nature of this issue, implementing successful policies in hospitals is troublesome as the use of smoke evacuation systems is only guidance not law. However, the Canadian Standards Association (CSA 2009) have submitted a standard which covers any type of smoke during surgery; suggesting that they believe the hazard is there.

This document states that smoke evacuation systems are needed within operating theatres to remove surgical smoke.

### *Raising awareness and changing practice*

Education is key to challenging negative attitudes. Ball (2010) suggested that surgeons need to be convinced that this is a matter of workplace safety and being a potential hazard is enough to warrant using smoke evacuation systems. Using testimonials from theatre staff expressing how surgical smoke has affected them, Ball (2010) believed is powerful enough to change these negative views. These health problems are only possibly linked to diathermy smoke as the two have not been successfully related (Pierce et al 2011).

There has been a case that demonstrated the ability of surgical smoke to have an effect on staff's health: an ENT laser surgeon contracted human papillomavirus DNA types 6 and 11 from one of his patients that he was treating (Hailmo & Naess 1991). He did not use a smoke evacuation system or a mask whilst conducting laser surgery, which could have potentially saved him. This demonstrated the need to utilise masks and smoke extraction devices to protect staff from subsequent harm. Unfortunately, this study does have its limitations due to the age of the paper and that this was looking at laser rather than diathermy smoke.

According to the National Institute for Health and Care Excellence (NICE 2007) increasing awareness of what needs to be changed, and why, are the vital first steps to improving practice. To improve compliance, Ball (2010) suggested that educational programmes should to be implemented to all members of the theatre team. Ulmer (2008) recommended that educators should take advantage of all resources when proposing educational programs. NICE (2007) suggested educational programmes such as group presentations, booklets, leaflets, posters and emails to be used when implementing change. This guarantees that everyone is subjected to the same standard information; which was found by Ball (2010) to improve the interconnectedness between surgeons and theatre staff when implementing preventative measures.

Schultz (2008) proposed that presenting educational material about the hazards changed staff perception of the risks and, subsequently, staff would become strong advocates for the use of smoke evacuation devices. To aid theatre staff's compliance, the AORN (2011) devised a tool kit to follow which assists the full implementation of policy and how to manage compliance. This kit suggested competency skills that staff must reach and provided a sample policy that can be implemented, along with posters that can be used to remind staff to protect themselves. Furthermore to improve compliance, Ball (2010) suggested that there should be



consequences enforced to staff who fail to comply with policy.

Changing practice is difficult especially with conflicting opinions between theatre staff and surgeons. The reasons behind surgeons' refusal generally seemed to be lack of evidence, but those who do use smoke evacuation equipment find that it is noisy and obstructs dexterity (Walczak et al 2011).

### *Development of equipment*

There are on-going developments to improve smoke evacuation machines and devices based on such feedback. For example, there are now machines with foot switches that activate and deactivate the smoke evacuator when the smoke is created to decrease noise (Ball 2010). As new developments arise, many companies allow trials of the newly developed equipment. By utilising this offer, surgeons can experience adaptations of the equipment which may change their views when it comes to noise and dexterity.

Schultz (2014) found that the noise problem could be due to the incorrect attachments being used. This can easily be remedied by contacting the manufacturer and getting expert advice about what product best suits their needs or to provide further education in the use of the equipment. The Royal College of Surgeons (RCS 2014) expects all surgeons to keep their 'professional knowledge and skills up to date' suggesting that they need to adapt their practice. The Royal College of Nursing (RCN 2014) found that surgeons' refusal to use smoke extraction equipment was due to them finding it cumbersome, which could arguably be seen as unwillingness or inability to adapt their practice. Spearman et al (2007) found this also to be the case in their study; however the comparison of consultant and registrar compliance is compelling. Only 45% of consultants extracted diathermy smoke in comparison to 70% of registrars. These results could suggest that there is complacency amongst consultants, or that registrars have been exposed to using these devices from the beginning of their training so for them this is standard operating procedure.

### *Recommendations*

The findings of this review suggest that noncompliance with extraction of diathermy smoke is most commonly due to staff knowledge and views on extraction devices. During this review there has been a variety of recommendations from organisations overseas and the UK, providing guidance on preventative measures. However, there is little in these recommendations about compliance. In this review, it was found to be extremely difficult to locate many credible documents about how to improve or maintain compliance. However, the literature

reviewed did provide some evidence to answer the research question.

### *Lack of knowledge*

As discussed previously, the review recommends introducing educational programmes, utilising audit days to give talks/presentations about the hazards and what staff can do to protect themselves. Other media should be used to establish that staff at different educational levels understand and use other tools, such as the AORN (2011) toolkit referenced.

### *Change opinions*

Surgeon compliance has been documented as challenging due to their opinions of the equipment. In an attempt to overcome these barriers, it is recommended there should be mandatory attendance to presentations. To ensure full attendance different times and dates must be available due to accommodate busy schedules. These talks could include representatives from companies presenting their products, allowing the surgeons to familiarise themselves with the equipment and to ask questions.

### *Limitations*

During this literature review a few limitations were found: firstly, this review was done with time constraints so only a specific amount of time was allowed for sourcing the research material. This may have had an impact on how explicit the search was. However, the search strategy was exhausted.

Secondly, there was a limited amount of literature on compliance, demonstrating that there is still a great deal of research to be done on this subject. The literature found may be seen as unrepresentative of the population due to the amount of literature available.

Thirdly, compliance is subject to a variety of other interventions. However, it was not researched whether financial constraints were a reason for noncompliance, which could possibly be another reason why compliance was low. Further research needs to look at financial constraints and compliance.

### *Conclusion*

As this review has demonstrated, there is a clear risk to staff health from diathermy smoke, however it is apparent that staff are not protecting themselves. Lack of education has been found to be the main cause of noncompliance with regards to occupational hazards, access to advanced evacuation equipment, and other precautionary measures. This review has suggested some readily available solutions to this problem. On reflection, theatre staff need to look at practices within their department to see if they can learn from these

findings and develop policies to improve the working environments for themselves and their colleagues.

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