

Pacemaker explosions in crematoria: problems and possible solutions

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J R Soc Med 2002;95:353–355

SUMMARY

The number of artificial cardiac pacemakers is increasing, as is the number of bodies being cremated. Because of the explosive potential of pacemakers when heated, a statutory question on the cremation form asks whether the deceased has a pacemaker and if so whether it has been removed. We sent a questionnaire to all the crematoria in the UK enquiring about the frequency, consequences and prevention of pacemaker explosions. We found that about half of all crematoria in the UK experience pacemaker explosions, that pacemaker explosions may cause structural damage and injury and that most crematoria staff are unaware of the explosive potential of implantable cardiac defibrillators. Crematoria staff rely on the accurate completion of cremation forms, and doctors who sign cremation forms have a legal obligation to provide such information.

INTRODUCTION

The artificial cardiac pacemaker saves lives and improves quality of life¹ and is the commonest active implantable medical device. In the UK, 17 000 pacemakers are implanted annually (290 per million), giving a pacemaker prevalence of 250 000 (Solesbury P, personal communication). Elderly patients now represent an increasing proportion of the paced population², so the prevalence of pacemakers in those who have died will increase. Wider indications for pacemaker insertion include the treatment not only of bradyarrhythmias but also of tachyarrhythmias, with devices capable of pacing, cardioversion, and defibrillation³. In the UK, a statutory question on the cremation form asks the attending physician whether the deceased had a pacemaker and if so whether it has been removed⁴. This is because of the explosive potential of pacemakers when heated.

The first reported case of a pacemaker explosion during cremation was in 1976⁵. The body of a 70-year-old man was cremated at 800 °C. After 5 minutes, four explosions occurred in rapid succession with a final explosion a few minutes later. In the wall of the cremator was a finger-sized hole half an inch deep. Among the cremated remains, there were five discs 'resembling the ends of rifle cartridges', a short length of wire and a metal plate. The device was identified as a zinc/mercuric oxide pacemaker. These

pacemakers explode on cremation because of the rapid formation of hydrogen gas which bursts the pacemaker casing⁶.

Today, most pacemakers have a lithium/iodine-polyvinylpyridine (PVP) battery—because of its greater longevity, the smaller cell size and predictable depletion⁷. Other pacemaker power sources have included zinc/mercuric oxide, nickel cadmium and plutonium-238⁸. Battery development plays a key role in pacemaker design because small-volume high-energy power sources are required. This requirement, the increasing pacemaker prevalence and the greater number of cremations in the UK (from 3 in 1885 to 44 169 in 1999, now accounting for over 70% of funerals)⁹ may result in increasingly powerful and frequent explosions in crematoria. We aimed to determine the frequency and consequences of pacemaker explosions in crematoria, and investigated the current procedures for preventing them.

METHODS

We sent a postal questionnaire to the managers of all 241 crematoria in the UK as listed in the Directory of Crematoria⁹. We posted second questionnaires to those crematoria that did not respond. There were two questions on the frequency of pacemaker explosions: (1) Have you ever had personal experience of pacemaker explosions in crematoria? (2) What do you estimate is the frequency of pacemaker explosions in crematoria? We also asked about the consequences of explosions and the procedures that were performed to ensure that pacemakers were not left in the body before cremation. We enquired about staff awareness of implantable cardiac defibrillators and whether

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a hand-held metal detector might be useful in identifying pacemakers in mortuaries.

RESULTS

The overall questionnaire response rate was 78%. Though 47% of the 188 crematoria staff who responded had personal experience of pacemaker explosions at some point in their career, those explosions were reported to be uncommon (Table 1). Indeed, 41% of staff, when asked to estimate event frequency, reported no events and 27% estimated events once in every 10 years. However, 5% of respondents reported pacemaker explosions occurring once or more a year.

Of the 71 crematoria that had reported distress or damage as a result of pacemaker explosions, the commonest consequences were the noise of the explosion and damage to the cremator doors and brickwork—32 (45%) and 30 (42%) crematoria, respectively. The cremator was damaged beyond repair in 3% of cases and in one case the explosions caused injury to staff. The remains of pacemakers were found after 15% of explosions.

The procedure for checking that pacemakers were removed before cremation was as follows. 99% of crematoria staff check the cremation forms to ensure that the doctor signing the form has confirmed that there is no pacemaker in the body. 54% of crematoria staff also discuss the case with the funeral director to check that the pacemaker has been removed from the body. Only 9% of crematoria staff ask the relatives whether a pacemaker is present. 16% make other enquiries (e.g. speaking to the coroner's office, mortuary staff, hospital, or medical referee or placing a reminder slip with the cremation form for the attention of the attending doctor).

Most crematoria staff believe that checking the cremation form is the best method of ensuring that pacemakers have been removed before cremation. However, only 5% of them knew about implantable cardiac defibrillators and their explosive potential (one centre

reported a large explosion caused by the cremation of a body containing an implantable cardiac defibrillator). 54% believe that a hand-held metal detector might help identify pacemakers and other implantable devices that could explode.

DISCUSSION

This is the first published report of the frequency and consequences of pacemaker explosions in crematoria. Though these explosions are infrequent, in some crematoria there is more than one explosion per year. Pacemaker explosions can damage the cremator, breaking doors or brickwork. The noise of an explosion may cause distress. Sometimes, pacemaker remains are found. Injury to staff is fortunately rare.

Today, most pacemakers are driven by the lithium/iodine-PVP energy source. At room temperature these devices are benign. However, during cremation, when temperatures reach 1300 °C (2400 °F) for 90 minutes, iodine forms a gas that rapidly expands, causing the pacemaker casing to burst. A chemical reaction also causes an explosion: at 180.5 °C lithium melts and reacts with the gaseous iodine to release in less than 1 second the energy which would be expended over several years (about 64 kcal/mol).

Pacemakers now in the design stage will be potentially more explosive and also more difficult to detect post mortem: both manufacturers and patients favour smaller pacemakers that have greater energy. Solid cathode, liquid electrolyte systems such as the lithium/carbon monofluoride and lithium/manganese dioxide pacemakers have greater gravimetric energy density (watt h/mm³) and are therefore likely to be future cardiac pacemaker power sources¹⁰.

Cremation forms must be completed by medical staff to prevent the inappropriate cremation of pacemakers. Our study demonstrates that most crematoria staff rely on a completed and accurate cremation form to ensure that pacemakers are not present in the body. Since it is against the code of practice of crematoria staff to open sealed coffins, they depend on others to provide accurate information. Indeed, many crematoria staff discuss the issue of pacemakers with funeral directors, who are able to inspect the body in an attempt to prevent the cremation of pacemakers.

As a result of the first reported incident, in 1976⁵, two supplementary questions were added to form B of the Cremation Act certificate. They remain in use and ask (a) Has a pacemaker or any radioactive material been inserted in the deceased (yes or no)?; (b) If so, has it been removed (yes or no)? If (b) is answered in the negative, the medical referee may, under Regulation 12 of the Cremation

Table 1 Frequency of pacemaker explosions in crematoria in the UK as estimated by crematoria staff

Frequency of explosions occurring in the UK	Crematoria staff reporting event at this frequency (%)
Never	41
Once every 10 years	27
Once every 5 years	14
Once every 2 years	6
Once a year	3
Greater than once a year	2
Not answered	7

Regulations (1930), prevent cremation⁴. Similar questions were advised for the coroner's form E, but have not been implemented. It has been argued that the cremation form should be abolished and the medical certificate amended to include questions about pacemakers as well as suspicion about the cause of death¹¹.

Despite the statutory questions on the cremation form B, we have found that some pacemakers remain in the body during cremation. There are several possible explanations for this. First, the doctor signing the form may mistakenly report that there is no pacemaker in the body or the form may be incomplete. As a result, pacemakers are left in the body. There is little doubt that this occurs: only 41% of forms presented to a crematorium were completed sufficiently for the staff to proceed without further enquiry¹². In another survey, 6% of cremation forms had incorrect or incomplete details of pacemaker or radioactive implants, with over 25% of forms being unsatisfactorily completed¹³. Secondly, the coroner's form E does not contain the statutory pacemaker question. With the coroner's certificate now accounting for about a third of disposals¹⁶, it may be that some pacemakers remain in situ. Thirdly, it is possible that only one pacemaker is removed from a body that contains two or more devices. Finally, pacemakers can migrate in the subcutaneous tissue, making detection by palpation difficult.

Pacemaker explosions are potentially costly for the crematorium owner and may lead to legal proceedings against funeral directors, physicians and health authorities to recover losses. A hand-held metal detector (such as those used at airports) might help detect pacemakers in the mortuary. Our study shows that many of those surveyed believe that such a device could be useful. This warrants further study. Other metallic devices (such as syringe drivers and prostheses) would also be detected, but this could be verified with reference to the deceased's medical case-notes.

Our study is a retrospective analysis of returned questionnaires. Probably there is under-reporting of the pacemaker explosions. Staff may not wish to mention these events and their recall may not be accurate. Such a discrepancy is apparent in our results because 47% of staff who responded reported personal experience of pacemaker explosions at some point in their career, but only 41% of staff estimated no events occurring in general. To our knowledge, there is no routine collection of data on explosions in UK crematoria. If this were done, we would have an accurate record of the frequency and consequences of explosions.

Our study shows how much crematoria staff rely on accurate and complete cremation forms. Physicians entitled to sign forms B and C must be aware of the legal and financial responsibilities of certification and the consequences when pacemakers are heated. Simple steps such as the duplication of the two statutory questions on form B to the coroner's form E, along with a question about implantable devices on the relatives' form A, might help reduce the number of explosions in crematoria. In addition, the routine placement of a warning label on the front of all the clinical notes of people with pacemakers and other implantable devices would alert the physician to the presence of potentially explosive material in the body.

Acknowledgments This study would not have been possible without the help of the staff of the UK crematoria, Mr RN Arber (president of the Cremation Society of Great Britain), Mr A Hurdley (senior mortician at St James's University Hospital, Leeds) and Mr P Solesbury (Medical Devices Agency). We thank them for their assistance and advice.

REFERENCES

- 1 Finkelmeier NE. Pacemaker technology: an overview. *AACN Clin Issues Crit Care Nursing* 1991;2:98-106
- 2 Aggarwal RK, Ray SG, Connelly DT, Coulshed DS, Charles RG. Trends in pacemaker mode prescription 1984-1994: a single centre study of 3710 patients. *Heart* 1996;75:518-21
- 3 Kusumoto FM, Goldschlager N. Cardiac pacing. *N Engl J Med* 1996; 334:89-97
- 4 Cremation Regulations, 1930 as amended by Cremation Regulations, 1979. *Statutory Rules and Orders*. 1930. No. 1016 as amended by S.I. 1979.No.1138
- 5 Morrell PJ. The exploding body. *Practitioner* 1977;218:109
- 6 Editorial. Hidden hazards of cremation. *BMJ* 1997;ii:1620-1
- 7 Holmes CF. The Bournier Lecture: electrochemical power sources—an important contributor to modern health care. *J Power Sources* 1997; 65:15-20
- 8 Greatbatch W. Pacemaker technology: energy sources. *Cardiovasc Clin* 1983;14:239-46
- 9 Arber RN, ed. *Directory of Crematoria*. London: The Cremation Society of Great Britain, 2000
- 10 Greatbatch W, Holmes CF, Takeuchi ES, Ebel SJ. Lithium/carbon monofluoride (Li/CFx): a new pacemaker battery. *Pacing Clin Electrophysiol* 1996;19:1836-40
- 11 Bateson MC. Cremation form should be abolished. *BMJ* 1999;318:811
- 12 Horner JS, Horner JW. Do doctors read forms? *J R Soc Med* 1998;91:98-106
- 13 Hawley C. Crisis in cremation. *BMJ* 1999;318:811
- 14 Horner S. Crisis in cremation. *BMJ* 1998;317:485-6