Waitemata
District Health Board
Te Wai Awhina

Report into the Operating Theatre Fire Accident
17 August 2002

Waitakere Hospital
Waitemata District Health Board
Final Report
29 September 2002

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Introduction

Waitakere Hospital

Waitakere Hospital is a small hospital in Waitakere City that provides maternity services, outpatient, rehabilitation and day surgery services. It delivers approximately 2,500 babies per annum and has one maternity operating theatre. As a level-one stand alone unit Waitakere Hospital only employs senior specialists.

Purpose

The purpose of this document is two part:

- To ensure the woman and her family, involved in this accident, are fully informed as to the events surrounding the accident and the actions being taken by Waitakere Hospital and the Waitemata District Health Board.
- To ensure that all surgical service providers in New Zealand have the opportunity to share in what was learnt during the investigation at Waitakere Hospital related to fire accidents in operating theatres.

This investigation has sought to be comprehensive and adopt a systems approach that supports a culture of continuous improvement. This culture can actively support health professionals, and their organisations, to improve the safety of healthcare to the benefit all New Zealanders.

This report should be read in conjunction with the following reports:

- NZ Fire Service - Fire Investigation Report; Benjamin Basevi
- Forensic & Fire Investigation Report; Marnix Kelderman

Waitakere Hospital agrees with all of the facts and findings contained within the Forensic & Fire Investigation Report. It also agrees with all of the facts of the New Zealand Fire Service Report, and all findings related to Waitakere Hospital. Some of the findings relate to Fire Service matters, which are outside of the expertise of Waitakere Hospital.

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Acknowledgements & Distribution

Acknowledgements

The Investigation Team would like to thank:

- The woman and her family for their patience and contribution to the investigation process. We greatly respect their strength and resolve at this difficult time.
- The staff involved in this incident for their co-operation and professionalism both during the incident and throughout the investigation process.
- Those people whom participated during accident reconstruction and testing of products associated with the accident.
- The New Zealand Fire Service for their technical expertise and commitment to improving the safety of the hospital sector.
- Those parties from the wider health sector who were co-operative and open with the Investigation Team when information was requested during this process.

Report Distribution

This report and its partner reports will be distributed to the following statutory bodies;

- Ministry of Health & Medsafe – Medical Devices Division
- Accident Compensation Corporation (ACC)
- Health & Disability Commissioner
- Electrical Safety Services (Ministry of Economic Development)
- Occupational Safety & Health Service
- Environmental Resource Management Authority
- New Zealand Fire Service

This report will also be forwarded to all of the following agencies:

- All District Health Boards
- NZ Nurses Organisation – Theatre Nurses Section
- Royal Australasian College of Surgeons
- Royal Australian & New Zealand College of Obstetricians & Gynaecologists
- Australian & New Zealand College of Anaesthetists
- Nursing Council of New Zealand & NZ Medical Council

Executive Summary

Event Description

On the morning of 17 August 2002, during an urgent caesarean section (LSCS) a fire occurred. The fire occurred immediately following the use of an electro-surgical unit (ESU) to coagulate a blood vessel.

A woman received full thickness burns to 16% of her body. The fire was fully extinguished by the staff present. Once extinguished the caesarean section was completed and the baby safely delivered. The baby was in-utero and unharmed. No other persons present received any injury.

Probable Fire Cause

The fire was a result of alcohol vapour from the skin preparation escaping from a crease in the drape and being ignited by a correctly functioning electro-surgical unit. There are at least ten parameters that must coincide for a fire such as this to occur. This includes the percentage of alcohol (ethanol) in the air must be between 3.3 and 19%, the vapour needs to be released from a sealed drape and the electro-surgical unit then needed to spark at the appropriate place and time

This type of fire is a very rare event. ACC have previously reported two incidents in New Zealand and studies suggest a very small number internationally. Ultimately this remains a random event that could never be entirely eliminated if alcohol based skin preparations are used in the presence of an electro-surgical unit.

Degree of Injury

The degree of injury suffered by the woman is severe. The severity of the injury is directly attributable to the intensity of the alcohol fire. Alcohol (ethanol) burns at 840 degrees celcius. The staff acting promptly to extinguish the fire minimised the potential for further injury to the woman, her unborn baby and staff present.

Accident Response

The fire incident was mitigated to some degree by the fact that the woman was under epidural anaesthetic, the rapid response of the staff using sterile water to extinguish the fire and the type of fire retardant synthetic drape, which allowed heat to vent from the area.

Statutory Obligations

Waitakere Hospital has an occupational health & safety programme that includes hazard identification and an employee assistance programme. The hospital also complies with the Electrical Safety Act 1997 and has authorised fire evacuation plans and staff fire training.

Origin of Fire

The forensic investigation determined the origin of the fire by examining the patterns of burning and the progression of the fire. This confirmed that there was sufficient alcohol vapour present to be ignited and to sustain burning. For this degree of injury, areas of flammable liquid had to be present under the drape to continue to produce vapour to sustain the fire.

Significant Contributing Factors

The most significant factor that contributed to the presence of alcohol vapour under the drape was the pooled alcohol based skin preparation. The pooling of the alcohol created sufficient alcohol vapour to sustain the fire. Pooling occurs because of run-off. The main contributory factors to run-off are:

- The standard sponge applicator, used with the bowl provided, will result in significant run-off of fluid resulting in pooling around the body losing 50-75% of the volume on contact with the body. The operator cannot control this run-off. The sponge is provided in the standard theatre pack for Caesarean Section.
- The skin preparation is colourless when applied and there is no visual effect of the pooling around the body.

System Change

There are a number of events that have occurred over time increasing the probability of pooling occurring. The two most significant events are the change to a low-density sponge to apply the skin preparation and the removal of the colour from the skin preparation. These events occurred approximately at the same time two years ago.

Actions

The following key actions are to be taken by Waitakere Hospital and the Waitemata District Health Board as a consequence of this accident and the subsequent investigation.

Alcohol Based Skin Preparation

Alcohol based skin preparations will cease to be used in the maternity theatre at Waitakere Hospital for obstetric surgery.

Each speciality within Waitemata District Health Board will undertake a review of the skin preparation solution currently being used with specific reference to benefit-risk analysis; and that this process is lead by that specialty's Clinical Director.

That surgical specialty's unable to justify the use of flammable skin preparation solutions change to a non-flammable solution. In those specialty's able to demonstrate clinical benefits that support the use of flammable skin preparation solutions, clear protocols will be implemented to control the risk.

The Applicator Sponge

That the skin preparation applicator, used in this accident, is removed from use within Waitemata District Health Board.

That forceps using dense weave foam rubber squares or Raytec gauze and forceps are retained as the preferred method for skin preparation application.

That any future changes in practice regarding applicator type are evaluated using specific and agreed criteria outlined in this report.

Procurement Processes	The processes used by Waitemata District Health Board to procure new clinical products are reviewed within the context of information learned during this investigation.
Staff Fire Training	Waitakere Hospital and the New Zealand Fire Service will work in partnership to review the current content and modalities of: (i) Fire training to ensure that specific workplace fire, electrical and hazardous substances risks are assessed, understood and managed as appropriate; and (ii) Fire Evacuation Plans.
Hazard Identification	That an independent Specialist Audit of hazardous substances be undertaken on the Waitakere Hospital site to evaluate the use of hazardous substances.
Hazard Notification	That all District Health Boards are issued a copy of this report to ensure wide knowledge regarding the risks of alcohol based skin preparations. Ideally this may reduce the risk of this type of accident occur again.

The Investigation Process

An Open Investigation

The investigation has been conducted as an open and transparent process. All of the agencies that have a statutory obligation to investigate this type of accident have been given access to all relevant and appropriate information.

The purpose of an open review is to ensure that what has been learnt from the review is widely available to all surgical centres in New Zealand and internationally.

It has been the intention of Waitakere Hospital to determine the cause of the fire and ascertain whether such an accident could be avoided, or the degree of harm minimised by changes in practices and/or service delivery.

Investigators

Waitakere Hospital immediately secured the services of a Forensic Fire Investigator and worked openly and collaboratively with the New Zealand Fire Service and the Electrical Safety Service to commence an investigation.

The accident has been reviewed by the following parties, and their colleagues, who have produced independent reports:

- Marnix Kelderman, Independent Forensic Scientist & Fire Investigator
- Benjamin Basevi, Deputy Chief Fire Officer, Waitakere City Fire District

These expert reports have been used to compile this report for the woman and her family, Waitakere Hospital and the wider health sector. Significant parts of this report are drawn from the Fire Investigation Report and the Forensic Investigation Report. This report has been compiled by:

- Rachel Haggerty, General Manager, Waitakere Hospital
- Kay Hogan, Professional Advisor, Nursing and Midwifery, Quality Advisor, Waitakere Hospital
- Dr Robin Youngson, Clinical Leader, Waitakere Hospital

The key investigations were all conducted and/or observed by:

- Marnix Kelderman, Independent Forensic Scientist and Fire Investigator
- Gavin Parish, Fire Safety Officer, New Zealand Fire Service –Auckland Region
- Kay Hogan, Professional Advisor, Nursing and Midwifery, Quality Advisor, Waitakere Hospital

Investigations

The following investigations were included in the review process:

- Staff interviews
- Fire event sequencing & time checks
- Fire scene reconstruction using material retained from the accident
- Operating theatre safety checks
- Electro-surgical unit inspection and testing
- Surgical drape experiments
- Applicator experiments
- Swabbing experiments

There is a reference in the NZ Fire Service Investigation Report that a bag containing open empty equipment packets, bowls & the second drape used may have been accidentally discarded. As these items were standard clinical supplies the NZ Fire Service does not regard this missing evidence as significant.

Description of Accident Events

Time Sequence

This is a summary of the time sequence of events. The full detail is contained within the Forensic & Fire Investigation report (p10 onwards).

The fire occurred in the Maternity Theatre, Hughes Block – Waitakere Hospital on the morning of the 17th August 2002.

The woman had been admitted to the Maternity Unit, at Waitakere Hospital the previous day in labour. She was transferred to the operating theatre and was prepared for a lower segment caesarean section (LSCS) with epidural anaesthesia.

The time from the first incision (06:20am) until the baby was delivered and moved to the recovery room (06:32am) was twelve minutes. The baby had been delivered two to three minutes earlier at approximately 6:29am / 6:30am. (The actual time was not recorded in the notes and is estimated from the recorded sequence of events.)

Excluding the preparation for and the actual caesarean section itself, when the baby was delivered, it is estimated that staff had a maximum of six minutes to react to and deal with the fire accident.

When the accident occurred an emergency bell was activated in theatre, alerting the maternity unit staff and calling for assistance, a 111 call to the New Zealand Fire Service and a 777 internal hospital emergency call were activated.

The New Zealand Fire Service Report outlines the exact details of calls received (page nine). The first 111 call was made at 06:21:00; the 777 call activated another contact with the Fire Service at 06:22:02. The NZ Fire Service arrived at 06:27:11.

The woman was transferred to Middlemore Hospital burns unit at 07:55 and the baby was transferred at 11:31.

Recognition of Fire

Something unusual was recognised by staff immediately following the use of the electro-surgical unit. The sound of the vapour igniting created a low, light "whoomph" sound. Staff stood back and questioned the noise.

The woman then noticed the heat and the anaesthetist felt the heat and saw a flame/shimmer. Staff immediately took steps to extinguish the fire with sterile water. Fire extinguishers were present but not used on the woman.

Post Accident Events

Care of the Woman

Waitakere Hospital actively sought feedback from the Consultant Plastic Surgeon caring for the woman as to the appropriateness of the burn care immediately following the accident. It was confirmed that the treatment was timely and appropriate for the type of injury sustained:

- The mother's burns had been immediately doused in copious amounts of sterile water at the time of the accident.
- The initiation of treatment for the serious burns, suffered by the mother, was commenced by the obstetrician and anaesthetist, after consultation with a Plastic Surgeon from Middlemore Hospital. This involved the dressing of the burns with gauze soaked in normal saline in readiness for transfer to Middlemore Hospital.
- The anaesthetist, who accompanied the woman and her mother to Middlemore, maintained analgesia en route; and on arrival handed care over to an anaesthetic colleague.

Injuries Sustained

The degree of injury suffered by the woman is severe. The severity of the injury is directly attributable to the intensity of the alcohol fire. Alcohol (ethanol) burns at 840 degrees celcius. The staff acting promptly to extinguish the fire minimised the potential for further injury to the woman, her unborn baby and staff present.

The injuries are full thickness burns (third degree) to 16% of the woman's body between her armpits and knees. The palmar surface of a patient's hand equates to 1% of body surface. The areas of burn are: right medial thigh 1.5 – 2%, left medial thigh 1.5 – 2%, right side of body (buttock to axilla) 6%, left flank 2%. The original verbal report from the Plastic Surgeon advised 12%, the discharge summary advises that it is 16% of her body.

At the time of the accident, the unborn baby remained in-utero and did not sustain any injury.

Care of the Baby

Following the completion of the Caesarean Section, the following actions occurred:

- At delivery, the baby was handed to the Clinical Charge Midwife who supported the baby.
- The safely delivered baby was then transferred to the care of the Independent Midwife and the Paediatrician on duty.
- The baby was transferred to Middlemore Hospital at 11:31am when an admitting Paediatrician was available to receive the baby.

The NZ Fire Service & St John Ambulance

The New Zealand Fire Service attended the accident, as did the Ambulance Service. Meetings held between Waitakere Hospital and these services identified that staff responded promptly and the fire service was present six minutes after notification.

The Fire Service and St John left the scene shortly after ascertaining the area was safe and secure. St John Ambulance returned to transfer the woman to Middlemore Hospital at 07:50.

Significant Incident Management

Notifications

The Director of Nursing & Midwifery for the Waitemata District Health Board attended the accident immediately. On arrival she undertook to contain the environment, arrange the necessary safety checks, secure a safe environment and return services to Waitakere Hospital. She was supported by the Manager of Maternity Services from North Shore Hospital, who was contacted, as Waitakere Hospital had to be closed to deliveries, as it had no operating theatre for 2.5 hours.

Senior Management Notification

Senior Manager Notification occurred at approximately 0820 notifying the following people:

- Chief Executive Officer, Waitemata District Health Board
- General Manager Waitakere Hospital who contacted the Operations Manager, Waitakere Hospital

The General Manager, Waitakere Hospital, went to Middlemore Hospital at midday to establish contact with the woman and her family.

Medsafe, the NZ Medicines and Medical Devices Safety Authority, were notified on Monday 19 August 2002.

Containment of the Environment

The following items were immediately secured by the Director of Nursing & Midwifery for the purposes of ensuring appropriate investigation:

- Electro-surgical Unit (ESU) Diathermy Unit (WDHB Asset Number WHL/03838A)
- Electro-surgical Pencils (Batch 53933)
- REM PolyHesive II pads (Batch 56067)
- Skin preparation solution used (bottle and remaining solution).
- Theatre table linen, patient gown and surgical drape

Electrical Safety Checks

Waitemata District Health Board Electricians carried out an examination of the electrical systems in theatre 08:45am, that morning. A residual circuit device test was carried out and on inspection they had not operated. They were subsequently tested and no fault was detected.

All remaining electrical theatre equipment was then checked. It was found to be operating normally and had been safety checked in the previous twelve months.

The theatre was also inspected by the Electrical Safety Service Electrical Inspector who confirmed that it was correctly set-up as a “body protected area” and met all requirements of the Electricity Regulations 1997.

Environmental Safety	As the electro-surgical unit and alcohol based skin preparation were suspected, the actual items were removed from the operating theatre. The use of "0.5% chlorhexidine in alcohol 70%" as a skin preparation solution in caesarean sections was immediately suspended across Waitemata District Health Board, pending the outcome of the investigation. It was replaced with aqueous iodine and subsequently aqueous chlorhexidine (chlorhexidine 0.015% & cetrimide 0.15%) solution, as they were readily available.
Maternity Services Continuity	Incoming maternity admissions for Waitakere Hospital were suspended until 09:00am. At this time surgical services resumed at Waitakere Hospital after the completion of the electrical safety checks of the theatre, replacement of the electro-surgical unit and the suspension of alcohol based skin preparation.

Cause of Fire

Fire Ignition

Three elements are required if a fire is to occur: an ignition source, fuel and an oxidiser.

The ignition source was most likely the spark created by the normally functioning electro-surgical unit. Testing confirmed that the electro-surgical unit was operating correctly at the time of the incident and no faults were detected.

The fuel for the fire was the alcohol based skin preparation solution (chlorhexidine 0.5% in alcohol 70%), used to clean the skin surface prior to the operation. The ignition temperature for this product is low, at 21 degrees Celsius. Alcohol burns intensely and invisibly, at 840 degrees Celsius, causing significant injury in a very short period of time.

The oxidiser was considered to be the oxygen in the ambient room air. The use of medical oxygen by the patient was not a contributory factor as it was too far from the ignition source. Anaesthetic gases made no contribution to the oxide (fire) as they were not in use during the procedure.

Rare Event

This type of fire is a very rare event. ACC have previously reported two incidents in New Zealand and proportionally a very small number internationally.

There are at least ten parameters that must coincide for a fire such as this to occur. This includes the percentage of alcohol (ethanol) in the air must be between 3.3 and 19%, the vapour needs to be released from a sealed drape and the electro-surgical unit then needed to spark at the appropriate place and time.

The NZ Fire Service Report and Forensic Investigation report give a detailed evaluation of these factors.

Origin of Fire

The forensic investigation determined the origin of the fire by examining the patterns of burning and the progression of the fire. The most severe areas of fire damage was to the left and right flank of the patient. These burns correlate with the damage to the surgical drape.

This confirmed that there was sufficient alcohol vapour present to be ignited and to sustain burning. For this degree of injury, and patterns of burning, areas of flammable liquid had to be present under the drape to continue to produce vapour to sustain the fire.

Alcohol Based Skin Preparation

The Forensic Investigation report outlines in some detail how the alcohol came to be present in sufficient volume to sustain a fire under the drape. The vapour that escaped from under the drape was ignited and the fire was sustained by the evaporation of alcohol based skin preparation pooled in the materials under the woman. Alcohol burns as a vapour and has a near colourless flame.

Tests conducted by the Forensic Scientists, evaluating standard theatre practice, confirm that between 200 to 250mls of skin preparation solution would have been applied to the woman. A large percentage of this volume would be present under the drape in the folds of the woman's skin, her body hair and as pooling around her body. The burn patterns to the materials surrounding this woman confirm that the fire occurred in areas where solution pooling had occurred as a consequence of run-off.

The pooling is a consequence of standard practice using the systems and tools supplied to the operating theatre. There was no burning to the surface of the woman's abdomen confirming that the alcohol known to be on the abdomen surface was dry.

The Electro – Surgical Unit (ESU)

An electro-surgical unit generates a high frequency electrical current, which, can cut tissue like a knife and/or cauterise bleeding blood vessels and capillaries. The operating theatres at Waitakere Hospital use the Valleylab Force 2 electro surgical unit. It was purchased in June 1996 and has been regularly maintained with annual checks as required by standard.

The unit was used correctly in monopolar mode to enable it to coagulate large bleeders, as may occur during a Caesarean Section procedure. The unit was set at the 40W level for this action. The unit can be set between 25W and 40W, to provide the coagulation action. In normal monopolar use the electro-surgical unit will create a spark, at all settings.

ESU Maintenance History

The Clinical Engineering Department of Auckland District Health Board has a contract to service clinical equipment at Waitakere Hospital. The Electro surgical unit used in the procedure was tested one month prior to the accident. All performance and electrical testing is valid, up to date and recorded.

ESU Testing & Results

Testing was conducted in the presence of Marnix Kelderman (Forensic Scientist), Michael Chopping (Electrical Safety Service), Terry Castle (NZ Fire Service), and staff of the Biomedical engineering service at the Auckland District Health Board.

The electro-surgical unit was tested and found to be functioning correctly, correctly operated. The fire was not caused by and any fault in the electro-surgical unit. The normal sparking action of the electro-surgical unit was the ignition source for the fire.

Surgical Drapes

The surgical drape used by Waitakere Hospital is a Kimberley-Clark product called 'Evolution 4'. This drape is designed to be used with alcohol based products and has been designed specifically to be resistant to combustion. In the opinion of the investigator it reduced the effects of the burning alcohol by allowing heat to vent away from the woman's body. This drape was more effective than traditional cloth surgical drapes would have been in these circumstances, as they did not ignite.

The drape is adhesive and seals around the planned incision area of a patient. The drape is designed for abdominal surgery and does crease and wrinkle around the pubic mound. The surgical drape trapped the vapour, which was then released and able to ignited by the electro-surgical unit. The drape was not originally designed to occlude alcohol vapour but has provided this function.

Contributing Factors

The Forensic Investigation Report confirms that the following factors were significant and contributed directly to this fire:

- The applicator supplied to apply the skin preparation allows too much liquid to be lost and subsequent pooling to occur around the body.
- Pooling of alcohol around the body.
- Flammable vapours trapped under the surgical drape
- The use of a flammable liquid as an antiseptic agent
- The ignition of flammable vapours by the electro-surgical unit
- The morphology and dynamics of the woman's body

Reduction of Fire Impact

The Forensic Investigation Report also confirms that the following factors reduced the impact of this fire:

- The use of the "Evolution 4" surgical drapes that exhibit fire retardant qualities.
- The actions of the staff present.
- The use of an epidural anaesthetic rather than a general anaesthetic.

Alcohol Based Skin Preparation

General

The pooling of alcohol around the body was a significant contributor to the degree of injury suffered by the woman in this accident. Once this had been determined the investigation team sought to answer three questions:

1. Is it necessary to use alcohol based skin preparation when performing a caesarean section?
2. If alcohol based skin preparation are recommended for use in caesarean section, what methods/practices could make it safer?
3. What volume of solution is required to make an effective skin preparation and what is the best form of application?

Use of Alcohol Based Skin Preparation

Alcohol based skin preparations are used commonly in hospitals around New Zealand. There is some national variation in practices by institutions, specialty and consultant surgeons.

The purpose of applying skin preparations to the surgical field is to reduce the incidence of post-operative wound infection by comprehensive cleansing and disinfection of the patient's skin prior to surgical intervention[1]. The incidence of this can be referred to as the surgical site infection rate.

The investigation team has determined that alcohol based skin preparations are used for two main reasons:

- Effective cleaning & disinfectaton of the skin surface, reducing bacterial count; and
- Rapid drying for the effective adhesion of adhesive drapes.

There is no direct evidence that the use of alcohol based skin preparations reduces surgical site infection rates when compared to aqueous based solutions in caesarean section procedures. They are not commonly used for gynaecological procedures and there is no expectation that the infection rate would increase if alcohol based skin preparations were no longer used. Appendix one contains significant references used to evaluate this issue. There is evidence that alcohol-based solutions are the most effective hand preparation for reducing microbial skin counts of surgical personnel.

Adhesive drapes are commonly used in theatres as they create a secure area for incision that assists to minimise the risk of infection. The adhesive caesarean section drape also assists to capture body fluids from the procedure. There is no evidence that care would be compromised if adhesive drapes were used with an aqueous based skin preparation.

[1] Perioperative Nurses Association, November 1998, *Standards and Guidelines for Safe Practice*

Product Knowledge

Although alcohol based skin preparations are used commonly in hospitals around New Zealand the Material Safety Data Sheet (MSDS) and the general product information is not well targeted to hospitals.

The MSDS only makes general reference to its flammability and is not specific to its intended use in an operating theatre. In addition the product is supplied without warning or information sheets and has a small flammability symbol. There is no evidence that the use of this product in theatre has been previously identified as potentially dangerous.

The Applicator

The sponge is provided in the standard theatre pack for caesarean sections. It is a standard item supplied to 14 hospitals/surgical centres in New Zealand.

The application techniques for skin preparations were tested to determine why pooling is occurring and large volumes of run-off are experienced. The standard sponge applicator supplied in the theatre pack was tested against three more other methods of application, the forceps with sterile cloth, forceps with sterile sponge and sterile hand sponge.

The sponge applicator used with the bowl provided, loses approximately 50 to 75% of its solution per application. Its low density and flexible handle means that the operator has no control over the volume loss. The introduction of the sponge has resulted in a five to six fold increase in the use of skin preparation over the traditional forceps and hand sponge techniques.

Colourless Skin Preparation

In this testing it was also clear that the presence of a colouring agent in the preparation greatly reduced the amount of run-off as it was possible to clearly see which areas had been prepared.

At approximately the same time as the applicator sponge was included in surgical packs the colour was removed from the chlorhexidine in alcohol skin preparation. These two changes are significant as there is no visual effect of pooled alcohol to draw the attention of theatre staff. The colourless pooled alcohol is absorbed into the material under the woman on the operating theatre table and is not visible to staff.

Changes over Time

The Forensic Investigation identified that there are a number of significant changes that have occurred over time that have contributed to the probability of this type of fire occurring. These changes over time are summarised as:

1. Theatres were historically hazardous as the environment contained potentially flammable & explosive anaesthetic gases.
2. Anaesthetic gases were changed to non-flammable compounds.
3. Electrical safety was improved with over current protection devices.
4. Surgical drapes changed from cotton to synthetic brand that are fire retardant.
5. Skin preparation solutions were largely iodine aqueous based products that are coloured and non-flammable.
6. Skin preparation solutions were changed to coloured alcohol based solutions
7. Skin preparation solutions changed to clear alcohol based solutions because of allergic responses to the dyes.
8. Application technique for skin preparation was changed from forceps to sponge applicator to improve speed of preparation.

These events, over time, developed an environment that posed a safety hazard. The risk of fire to a patient remains lower than other hazards in theatre.

Clinical Practice

Clinical Practices

The senior medical specialists, nursing, midwifery and technical staff in theatre at the time of the accident are some of the most senior and experienced in employment at Waitakere Hospital. The clinical procedures and practices followed by the staff are known to be consistent with those of clinical colleagues in similar environments throughout New Zealand. There is some minor national variation by institution, specialty and consultant obstetrician.

The clinical practice of the individual staff in theatre during this accident varied in no way from that in previous cases. The Investigation Team was unable to identify any omissions or variance of clinical practice by any of these team members that has contributed to the occurrence of this accident.

The actions of the healthcare practitioners involved exceeded expectations. They provided a reasonable standard of care in extremely unusual circumstances placing the well being of the woman and the safe delivery of the baby first, before considering their personal safety.

Safe Systems

The operating theatre environment, and standard surgical / anaesthetic procedures, contain many potential hazards, some of which are potentially life threatening. Modern surgical practice embodies a complex 'systems approach' to the management of potential hazards to allow safe patient care, even in the event of sudden emergencies such as a Caesarean Section. The design of the operating theatre environment, the standardisation of procedures, the control of materials, the safety features of equipment, and the professional training of medical, nursing and operating theatre staff seek to combine to minimise the potential of injury to patients.

In this context, the accidental fire that occurred is an event of very low probability, compared with many other potential hazards. In our investigation and its recommendations, we have sought to balance the risk and benefit of suggested changes to practice.

Inter-related Systems

The NZ Fire Service summarises the probable root cause of the accident as the failure of a range of inter-related systems that do not include the necessary information to ensure the safest management of fire risk. These systems include:

- National health care service provider guidelines
- Manufacturer and supplier information on equipment & products
- Product procurement, assessment and acceptance processes.
- Equipment procurement, assessment and acceptance processes
- Fire and hazardous material in-service training programmes
- Relevant clinical protocols

Occupational Health & Safety

Introduction

This fire accident requires a focus on the health and safety aspects of the events. The rapid response of the staff, the "Evolution 4" drape, regular fire training and the rapid response of the staff using sterile water prevented any injury to staff occurring during the accident.

Response of the Staff

The staff immediately responded to the fire. They worked effectively as a team and achieved key staff safety outcomes:

- The emergency call system was activated alerting the unit to a problem.
- A 777 call was placed notifying the telephone office that notified the Fire Service. This was an appropriate response. A fire alarm release may have required evacuation of the unit and would have raised concern and potentially compromised the care of other women that was not necessary.
- Staff knew the location of fire extinguishers and sterile water. The sterile water was used immediately; the fire extinguishers remained in theatre during the delivery of the baby in case of any other unknown fire event. At this time the staff were not certain of the cause of the fire.

Staff Safety

The fire, although causing serious harm to the woman, did very little damage to the materials surrounding the woman. This is combination of alcohol burning as a vapour above the materials and the "Evolution 4" drape. The drape is a petroleum-based product and exhibits fire retardant properties. It withdrew from the fire and did not ignite. The lack of flammable materials around the patient contributed to the safety of the staff and the woman.

The presence of sterile water in theatre, the presence of an emergency call bell and access to fire extinguishers provided the tools the staff needed to assist the woman and protect themselves.

Hazard Identification & Management

The operating theatre in maternity routinely completes hazard identification sheets and has a Health & Safety officer. The hazard identification was last completed in June 2002.

Although hazardous goods are recognised on the identification sheet the flammability risk was not explicitly identified. This is contributed to by the quality of the Material Data Safety Sheets (MSDS). This sheet does not outline the risks of the product in its normal use in operating theatres. The NZ Fire Service have identified that the flammability sticker does not have good visual impact.

Current Fire Training

All of the staff involved had complied with the need for annual in-service fire training updates. This training is not specifically for operating theatres but does cover the core elements of safety during a fire incident.
Fire training is provided in general to all staff and includes:

- Fire Procedures
  - Immediate Actions
  - Alarm Activation
- Fire Evacuation Plans
  - Three Levels
- Fire Safety Information
  - Automatic Fire Sprinkler Systems
  - Manual Fire Alarm System
  - Local Smoke Detection System
  - Automatic Smoke Control Doors
- Hand Operated Fire Fighting Equipment

Fire Training Improvements

The NZ Fire Service has identified an opportunity to improve fire training by targeting a programme specifically for operating theatre staff. It is important to note that this does not reflect on the very effective response during this accident. A review should enable the inclusion of awareness of the risks of hazardous substances used in the theatre environment.

The Fire Service also identified that although water was the best way to extinguish a fire on a person the next best opportunity is a fire blanket rather than a fire extinguisher. The presence of a fire blanket in a recovery room needs consideration.

Staff Support

The Director of Nursing & Midwifery and the NSH Manager of Maternity Services were present very soon after the accident. They identified the key staff involved and offered initial support. The staff members involved were asked to provide written statements regarding the incident.

The Obstetrician, Anaesthetist and Clinical Charge Midwife were pivotal in providing support to the team involved immediately following the event. Interviews regarding the incident commenced on Monday 19 August and a group debrief was organised for Wednesday 21 August.

Support has been on-going for this team throughout the investigation process both formally through facilitated and informal de-briefs and access to the Employee Assistance Programme. Briefing meetings and contact with management have been maintained as the review has progressed. Staff were also involved in the experimental and assessment work regarding what may have contributed to the fire. Team de-briefings occurred after the interviews and written statements had been completed.

Family Support	Waitakere Hospital has explicitly made all information in the investigation of the accident available to the woman and her family. Middlemore Hospital has provided significant clinical services to the woman and her baby.

Conclusions

The Accident

The early recognition of fire and the appropriate actions of the staff minimised the degree of injury and prevented any further injury to themselves or the woman's support people.

The baby was delivered safely and as quickly as possible in the circumstances. The woman received appropriate treatment and was transferred safely.

The Cause of Fire

This investigation process has concluded that the accident was a rare event that may happen when alcohol based skin preparations are used with an electro-surgical unit. The fire started as a consequence of the pooling of the skin preparation around the woman enabling sufficient quantity of vapour to be present. The pooling of the alcohol based skin preparation around the body of the woman contributed to the extent of injuries suffered.

The adhesive drape acts to trap the vapour developed from the pooling but on this occasion there was a sufficient crease in the adhesive layer to enable vapour to be present at the specific location where the electro-surgical unit was used. The "Evolution 4" fire retardant drape is not originally designed to occlude alcohol vapour but by its adhesive nature it has provided this function.

Clinical Practice

It is apparent that there was no failure or operator error in the use of the electro-surgical unit. In addition no clinical practice error has occurred and the staff followed standard practice, with the clinical tools supplied, to apply the skin preparation.

The Pooling of Alcohol

The pooling of the alcohol based skin preparation occurred because of three critical changes to the process of skin preparation prior to surgery:

1. The common use of alcohol based skin preparations for their positive attributes in controlling skin bacteria and drying quickly.
2. The removal of the colouring agent from the chlorhexidine product by the manufacturers as a response to issues of allergic reaction and aesthetics of the patient post operation. This removed the visual effect of pooling.
3. The change to a low density sponge applicator with a flexible handle that cannot be controlled by the operator to eliminate or reduce run-off.

Skin Preparations

For obstetric and gynaecological surgery there is no evidence to suggest that moving to aqueous based skin preparation products only, poses any increase in risks such as surgical site infections. This change would obviously eliminate the risk of alcohol based fires during the procedures using an electro-surgical unit.

Mitigation of Risk

In services that may need to still use an alcohol based skin preparation for purposes of managing surgical site infection risk, clear policies need to be implemented. These policies need to consider the following factors that pooling can be controlled by:

1. A controlled technique to apply the skin preparation, such as a forceps and gauze, as it reduces the volume of skin preparation required.
2. Using sterile towels in the surgical pack to gather any run-off and remove the towels prior to the drape being placed over the patient.
3. The use of a coloured staining product as it will then be more easily controlled and any pooling will have a visual effect allowing remedial actions to be taken prior to draping patients.

Occupational Health & Safety

Waitakere Hospital has a hazard management system and actively supports its health and safety policies and procedures including an employee assistance programme. The lack of knowledge about the hazard posed by this product is contributed to by the poor MSDS information sheet and the lack of warning materials supplied with the product.

In addition, Waitakere Hospital has demonstrated its compliance with key requirements such as; fire training, the Electrical Safety Act 1997, and significant incident management.

Recommendations & Actions

Introduction

The following recommendations are to be implemented from this report:

Alcohol Based Skin Preparation

There is no compelling evidence to support the use of alcohol based skin preparation as a pre-operative skin solution when performing a Caesarean section operation. Based on this finding the following actions will be taken:

- Alcohol based skin preparations will cease to be used in the maternity theatre at Waitakere Hospital for obstetric surgery.

It is further required:

- That each surgical specialty within Waitemata District Health Board undertakes a review of the skin preparation solution currently being used with specific reference to risk-benefit analysis; and that this process is lead by that specialties Clinical Directors employed by the Waitemata District Health Board.
- That surgical specialties within Waitemata District Health Board unable to justify the use of flammable skin preparation solutions change to a non-flammable solution.

Skin Preparation Applicator

This investigation has identified the use of the low-density foam applicator as a key contributory factor in this accident. The physical characteristics of this foam make it difficult to contain solution run-off with subsequent pooling unavoidable. It is recommended that:

- The skin preparation applicator, used in this accident, is removed from use within Waitemata District Health Board.
- Forceps using dense weave foam squares or Raytec gauze and forceps are retained as the preferred method for skin preparation application
- Any future changes in practice regarding applicator type are evaluated using specific and agreed criteria that includes:
  - ✓ Absorbency of applicator;
  - ✓ Solution run-off;
  - ✓ Solution loss;
  - ✓ Coverage and application;
  - ✓ Impact on theatre time;
  - ✓ Cost effectiveness.

- Each surgical specialty operating at Waitemata District Health Board documents this decision making process.

Use of Alcohol Based Skin Preparation

In those specialty's able to demonstrate clinical benefits that support the use of flammable skin preparation solutions, the following recommendations apply:

- That the use of a coloured product is preferred to all colourless flammable solutions as it allows instant recognition of solution application, run-off and any potential pooling hazard.
- That medical suppliers provide Material Data Safety Sheets (MSDS), for each flammable solution, that are specific to their use, storage, the management of spills and fire hazard information in the operating theatre environment.
- That when a flammable skin preparation solution is used, the following practices are implemented:
  - ✓ The amount of body hair removed is sufficient to allow good contact and seal of the incise drape to the patients body;
  - ✓ That the location of the incise drape is such that there is the maximum adhesive zone surrounding the incision site.
  - ✓ That a quantity range of skin preparation solution per procedure is determined and adhered to.
  - ✓ That sterile gauze pads, or equivalent, are packed around the patients body prior to application of the skin solution. These pads will capture pooling solution. At the completion of swabbing, the gauze pads are removed and secured away from the patient and staff in a lidded bucket waiting to be discarded at the completion of the surgical procedure.
  - ✓ That the maximum time (clinically indicated) is allowed for the solution to dry before draping the patient. In those cases, when there is insufficient time, the solution must be wiped off.
  - ✓ That areas on the patients body when pooling could occur, are wiped to removed the solution.
  - ✓ That the surgical drape used has fire retardant properties.

Procurement Processes

That the processes used by Waitemata District Health Board to procure new clinical products be reviewed within the context of information learned during this investigation. Specific areas regarding review are:

- Rationale underpinning changes to products
- Criteria for assessing and selecting products
- Hazard identification, and
- Authorities for making changes

Clinical Protocols to Use Alcohol Based Solutions

That Clinical Protocols and associated training is instituted that manage the potential risks of flammable substances:

Protocols need to explicitly state the:

- Volume of solution to be used;
- Type of applicator to be used;
- Type of solution container to be used;
- Catchment and removal of solution run-off;
- Drying times;
- Drape type to be used in surgical procedure with consideration of drape permeability;
- Identification of anatomical areas in which pooling could occur and strategies for removing accumulated solution;
- Storage and management of the flammable substance; and
- Mandatory staff training requirements.

Staff Fire Training

Whilst the investigation found that staff training met organisational requirements, it is recommended that the following occur.

That Waitemata District Health Board and the New Zealand Fire Service work in partnership to review the current content and modalities of:

- Fire training to ensure that specific workplace fire, electrical and hazardous substances risks are assessed, understood and managed as appropriate; and
- Fire Evacuation Plans.

That induction / orientation programmes for staff entering the operating theatre environment are reviewed within the context of the recommendations made.

Hazard Identification

Current hazard identification processes are up to date and meet organisational requirements.

- In the interests of continuous improvement, it is recommended that an Independent Specialist Audit of hazardous substances be undertaken on the Waitakere Hospital site to evaluate this.

Hazard Notification

To ensure wide knowledge regarding the risks of alcohol based skin preparations this report will be promulgated widely to ensure the risk is mitigated nationally.
