PRIMARY RESPONSE INCIDENT SCENE MANAGEMENT (PRISM):
GUIDANCE FOR THE OPERATIONAL RESPONSE TO CHEMICAL INCIDENTS

VOLUME 1: STRATEGIC GUIDANCE FOR MASS CASUALTY DISROBE AND DECONTAMINATION

Second Edition

R.P. Chilcott , J. Larner & H. Matar

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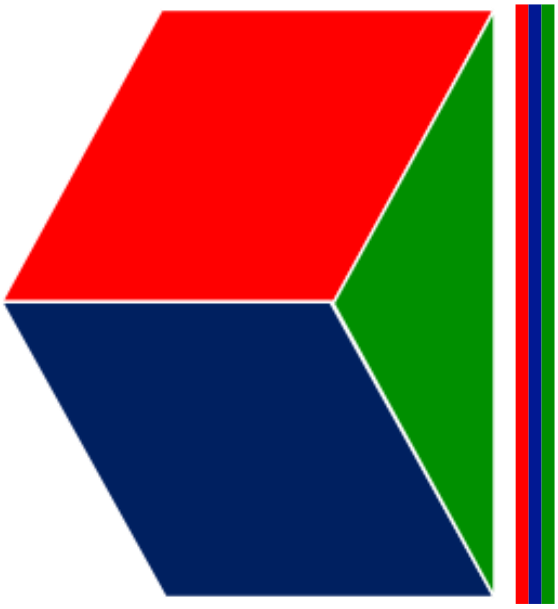

Primary
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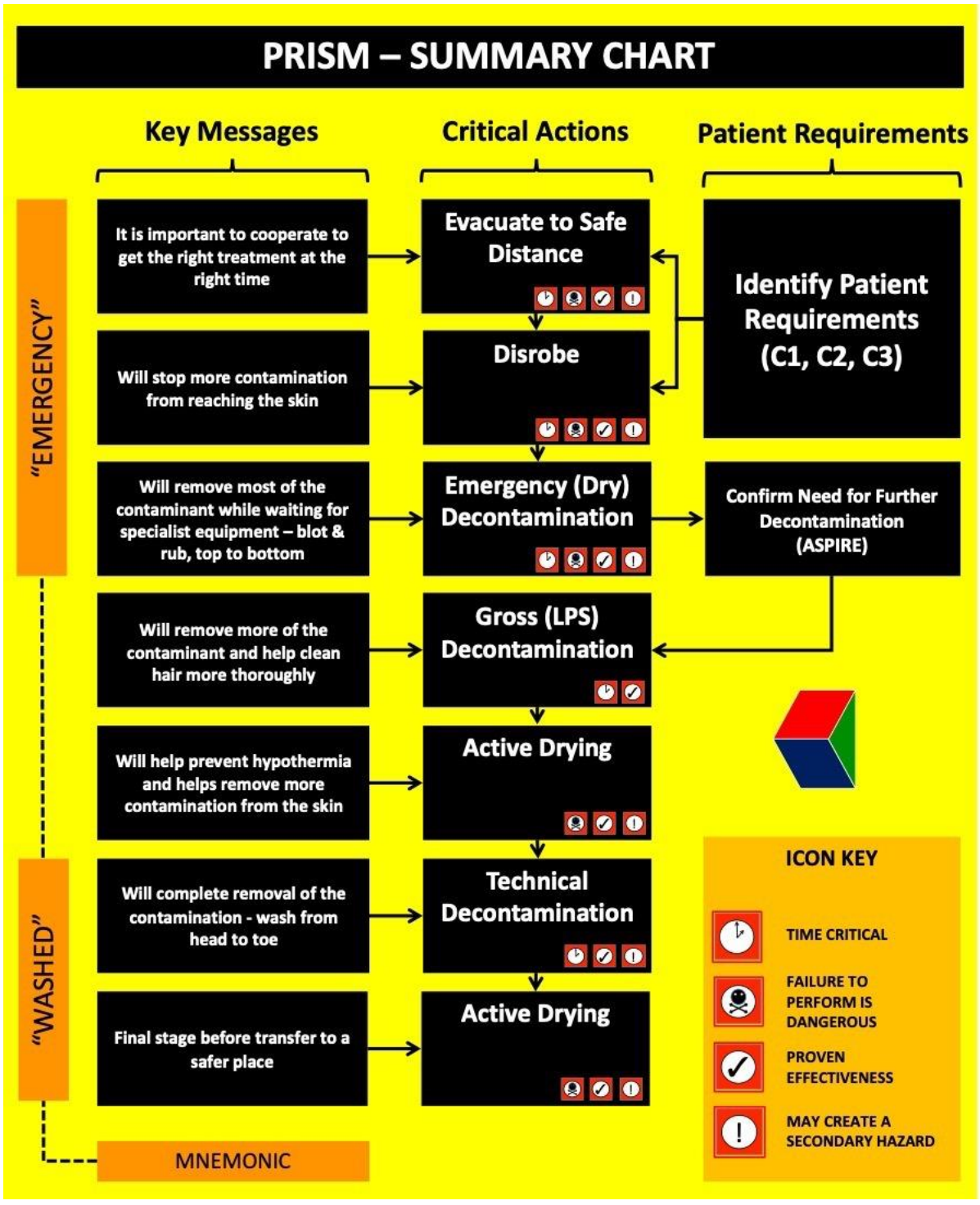
PRISM GUIDANCE – VOLUME 1

Second Edition

PRISM Incident Response Summary



Editors

Robert P Chilcott
BSc(Hons), MSc, PhD, CBiol, ERT, FRSB, FRSC

Joanne Larner
BSc(Hons), MSc, PhD, CChem, MRSC

Hazem Matar
BSc(Hons), MSc, PhD, MRSC

Main Contributors

Robert P. Chilcott
BSc(Hons), MSc, PhD

Joanne Larner
BSc(Hons), MSc, PhD

Hazem Matar
BSc(Hons), MSc, PhD

Nevine Amer
BSc(Hons), MRes

Mark Barrett
BSc(Hons)

Adam Durrant
BSc(Hons)

Philip Hughes
BSc(Hons)

Philip Lees

Devanya Mahalingam
BSc, MSc

Kate McCarty-Barnett
BS, MS, EdD

Andreia Pinhal
BSc(Hons), MSc

Samantha Rivers
MSci

Elliot Thomas

Other Contributors

Parivash Ashrafi
BSc(Hons), PhD

Valeria Catalani
BSc(Hons), MSc

Toni Jackson
BSc(Hons), MSc

Emma Jasper

Neil Redding

Joseph Reppucci
BS, MS

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Foreword

The Primary Response Incident Scene Management (PRISM) series was written to provide authoritative, evidence-based guidance on mass patient disrobe and decontamination during a chemical incident. The PRISM documentation comprises three volumes:

Volume 1: Strategic Guidance

Presents a review of best practices, collates available evidence and identifies areas that require further investigation. The document is relevant to senior incident responders (e.g., Incident Commanders) and those responsible for emergency planning and civil contingencies, as it describes the supporting technical information that underpins the rationale for each stage of disrobe and decontamination and highlights potential issues or challenges.

Volume 2: Tactical Guidance

The second volume provides an overview of the processes involved in mass patient disrobe and decontamination and the rationale that underpins each process. The document does not include supporting technical information or potential challenges. Volume 2 has particular application in the training and exercising of first responders and officials involved with domestic preparedness and emergency management.

Volume 3: Operational Guidance

The salient features of mass patient disrobe and decontamination are presented in Volume 3, which aims to provide all Federal, State, Tribal and local first responders with a simple, readily accessible guide to critical aspects of the incident response processes.

The underpinning basis of the PRISM guidance documentation is scientific evidence accrued from a six-year program of research sponsored by the Biomedical Advanced Research and Development Authority (BARDA), the aim of which is to ensure that all patients exposed to potentially hazardous chemicals receive the most effective treatment possible at the earliest opportunity.

Table of Contents

Executive Summary

Overview

This document (PRISM Volume 1) provides a detailed summary of the scientific evidence which supports revisions to mass patient decontamination protocols and practical guidance for their implementation. The majority of the underpinning research was derived from a six-year program of laboratory, human volunteer and field trials funded by the Biomedical Advanced Research and Development Authority (BARDA). The document also draws on best practices identified from contemporaneous or prior research and so represents a collation of technical knowledge acquired over the past decade. In particular, this document presents new evidence which identifies hair as a potential hazard due to the relative ineffectiveness of aqueous-based decontamination strategies for oil-soluble contaminants.

What's New

This second edition of the PRISM guidance incorporates a large body of new evidence pertaining to emergency (self-care) decontamination, hair decontamination, the effects of combined decontamination strategies ("Triple Protocol") and the interactions of chemicals with hair. In addition, a decision-aiding tool ("ASPIRE") has been derived to help responders determine the need for decontamination. This is available as a hard-copy 'ready reckoner' and an *on-line application* on the National Library of Medicine's CHEMM (Chemical Hazards Emergency Medical Manual) website. The overall incident response process has been organized into two components; Initial Operational Response (IOR) and Specialist Operational Response (SOR). Potentially life-saving actions that can be undertaken before the arrival of specialist assets are established during the IOR, with the subsequent use of optimized procedures (based on the availability of existing equipment) during the SOR.

Organisation of Information

The original structure of the PRISM guidance has been retained in that there are three documents tailored to the strategic (Volume 1), tactical (Volume 2) and operational requirements (Volume 3) of end-users. This document (Volume 1) reviews the technical evidence, identifies capability gaps and describes the corresponding rationale which underpins the revised incident response process. Volume 2 is more appropriate for training and exercising, as it focuses on the practical aspects of the incident response with an accompanying rationale but no supporting technical information. Volume 3 summarizes only critical, practical elements of the response process and so provides a readily retrievable source of information which may be of use during an incident response.

Remit and Scope of Guidance

The response processes outlined in this document have been designed for generic applicability for chemical CBRN and HazMat incidents and should be scalable taking into account the availability of local resources and assets. The recommendations in this document provide an evidence-based framework that may be appropriately modified according to the nature of the incident using established hazard or risk assessments.

This guidance covers the response period following recognition that a CBRN or HazMat incident has occurred up to the point where patients will be evacuated from the warm zone following technical decontamination. This guidance document does not address issues relating to the planning or operational delivery of the response (e.g., standard operating procedures, risk assessments, equipment configuration, triage points, etc.) as these will be region-specific and reflective of local practices.

Additional Resource Requirements

Whilst every effort has been made to utilize existing equipment and resources, the revised response process has highlighted several areas which require review. These are:

- The provision of suitable quantities of absorbent material on emergency response vehicles for instigating emergency dry decontamination.
- Increasing the number of Fire Department personnel required to deliver Ladder Pipe System decontamination to accommodate at-risk ("C2") patients.
- Provision of wash cloths and towels for technical decontamination.
- Ensuring logistics are in place to deploy blankets and/or temporary overclothes to protect patients from hypothermia following wet decontamination. This is of particular relevance to colder regions.
- Development and provision of appropriate communication material.

Glossary of Terms and Abbreviations

Term or Abbreviation	Definition or Explanation
10:10 technique	A method of dry decontamination that involves blotting an area of skin for ten seconds followed by rubbing (wiping) for a further ten seconds.
ASPIRE	Algorithm Suggesting Proportionate Incident Response Engagement. A mathematical model to predict the residual amount of chemical skin contamination at a given time post exposure.
BARDA	Biomedical Advanced Research and Development Authority. Part of the US Government's Health and Human Services (HHS) Office of the Assistant Secretary for Preparedness and Response (ASPR).
C1	Patient Category 1: individuals who are able to understand instructions and perform activities without assistance.
C2	Patient Category 2: individuals who are *either* unable to understand instructions *or* unable to perform activities without accommodation or assistance.
C3	Patient Category 3: individuals who are unresponsive, have life-threatening injuries or require extensive accommodations or assistance.
DIM	Detection, Identification & Monitoring.
Disrobe	The process of removing contaminated clothing from exposed individuals.
DME	Durable Medical Equipment. This term encompasses a diverse range of items such as wheelchairs, hearing aids, eye glasses, walking canes, insulin pumps and oxygen cylinders.

Emergency Decontamination	The first decontamination stage, which should be performed as soon as practically possible. This term replaces the use of "interim decontamination" or "immediate decontamination". Emergency Decontamination forms a major component of the Initial Operational Response and may be performed using dry (default) or wet methods.
Emergency (Self Care) Decontamination	See Emergency Decontamination.
EMS	Emergency Medical Service
FD	Fire Department
Gross Decontamination	The second stage of decontamination, which represents the start of the "Specialist Operational Response" and is generally performed using the "Ladder Pipe System".
Initial Operational Response	The foremost response activities undertaken at the earliest opportunity, including evacuation, disrobe and emergency decontamination.
IOR	See Initial Operational Response.
LEP	Limited English proficiency.
LPS	Ladder Pipe System of decontamination.
Non-Ambulatory Response	The action pathway for all patients that meet the C3 criteria and C2 patients for whom the Standard Response would be inappropriate.
PPE	Personal Protective Equipment.
POR	Primary Operational Response.
PRISM	Primary Response Incident Scene Management. Guidance for the Primary Operational Response which includes the Initial and Specialist Operational Response phases of a chemical incident.
Rinse-in Effect	The transient enhancement of the dermal absorption of skin surface contaminants caused by the use of water during decontamination.

Self-Care Decontamination	This is the standard terminology used in National Planning Guidance to describe the initial actions that can be undertaken by patients to protect themselves from the toxic effects of chemical contamination before first responders arrive at the scene. For the purpose of the PRISM guidance, this has been integrated into Emergency Decontamination (see above). The use of the word "emergency" emphasizes the time-critical nature of this action.
SOR	See Specialist Operational Response.
Specialist Operational Response	Specialist Operational Response: procedures or protocols that require specific assets or resources, such as PPE, the Ladder Pipe System of decontamination or technical decontamination units.
Standard Response	The action pathway for all patients that meet the C1 criteria and C2 patients requiring minimal accommodations or assistance. The alternative action pathway is the Non-Ambulatory Response.
TD	See Technical Decontamination.
Technical Decontamination	The third stage of decontamination, which requires the deployment of functional decontamination units as part of the Specialist Operational Response.
Thorough Decontamination	See Technical Decontamination.
Triple Protocol	The recommended incident response process that combines dry, Ladder Pipe and Technical Decontamination.
Wash-in Effect	See Rinse-in Effect.
Wet Decontamination	Generic term for decontamination procedures which require water, such as the Ladder Pipe System and Technical Decontamination.

Introduction and Overview

The purpose of this document is to provide evidence-based guidance for responding to a major incident involving exposure of civilians to hazardous chemicals. The Primary Operational Response (POR; Figure 1) is structured into an Initial Operational Response (IOR) followed by a Specialist Operational Response (SOR). The PRISM (Primary Response Incident Scene Management) guidance addresses the main features of the Primary Operational Response and thus covers both the Initial and the Specialist Operational Response.

The IOR provides potentially life-saving interventions in the absence of specialist equipment and merges into the SOR as specialist assets and resources become available. The overriding objective of the POR is to ensure that all patients receive the best possible treatment at the earliest opportunity.

The operational guidance provided in this document is based on best practice supported by scientific evidence. Each response element has been critically evaluated in terms of current practices, prior evidence and new evidence, with knowledge gaps or uncertainties highlighted to facilitate an objective assessment of the recommendations.

The most recent evidence (1-28) was acquired from laboratory experiments, volunteer studies and exercises arising from a program of work funded by the Biomedical Advanced Research and Development Authority (BARDA), part of the Health and Human Services' Office of the Assistant Secretary for Preparedness and Response (ASPR).

Additional evidence was identified from a literature search using the National Library of Medicine PubMed database. Search terms were: "mass decontamination", "ladder pipe system", "disrobing" and "CBRN". Internet search engines were used to ensure that other articles (e.g., government reports or other authoritative reviews) were retrieved by the literature search.

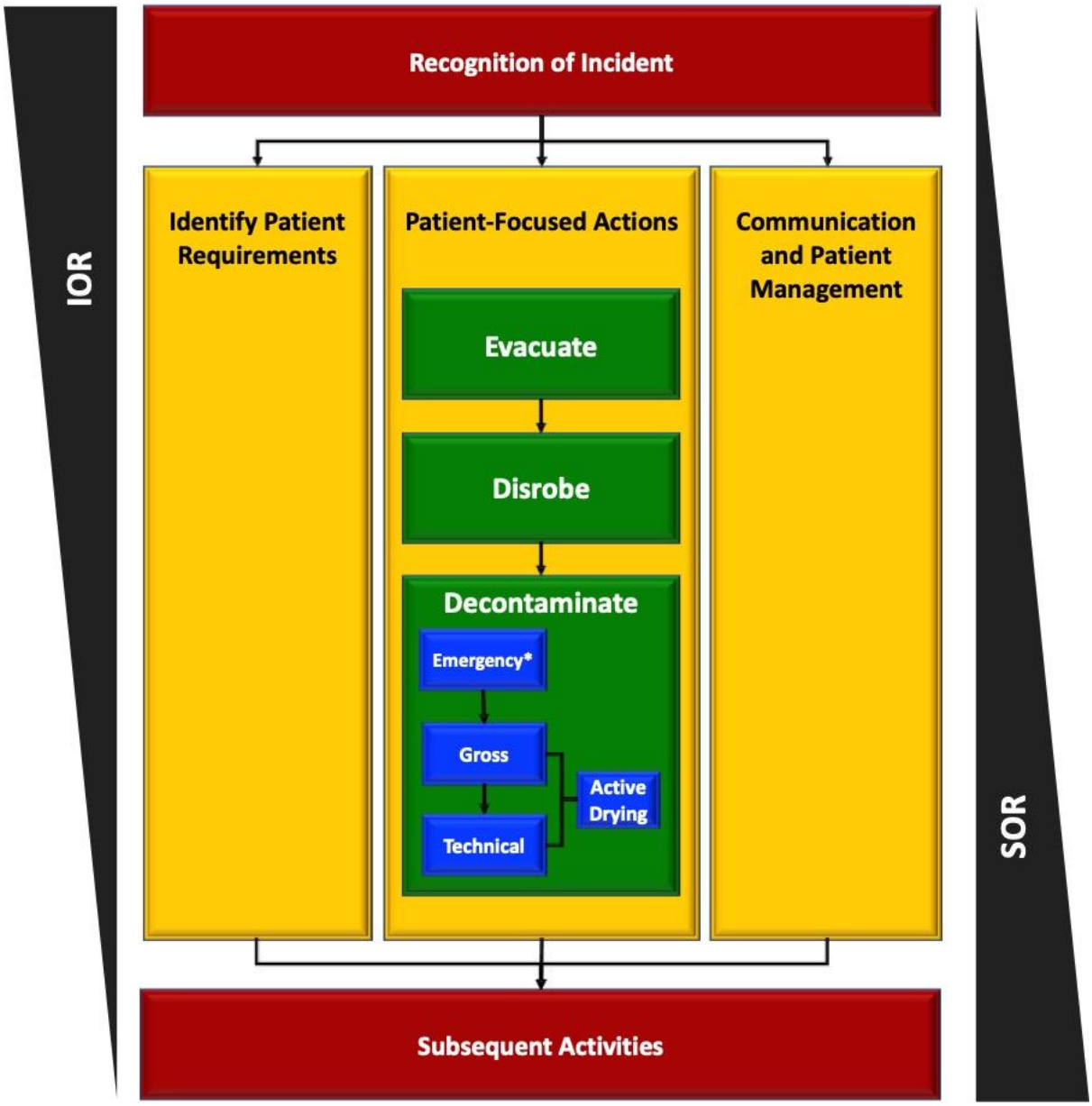

Figure 1: Constituent elements of the Primary Operational Response. The Initial Operational Response (IOR) predominantly covers first responder activities such as supervising evacuation, disrobe and emergency decontamination. *The phrase "emergency decontamination" is synonymous with "self-care decontamination" used in the US National Planning Guidance and replaces historical terminology such as "interim" or "immediate". The Specialist Operational Response (SOR) phases in with time, starting with the implementation of gross decontamination and subsequent deployment of technical decontamination units. Note that "recognition of incident" and "subsequent activities" are outside the scope of this guidance document. The patient-focused actions are delivered via "standard" or "non-ambulatory" response pathways.

The Three Pillars of the Primary Operational Response

The overriding objectives of the POR are to maximize initial survivability and minimize long-term sequelae in individuals who have been accidentally or deliberately exposed to toxic chemicals. The three "pillars" that support these objectives are an understanding of individual needs (patient requirements), an effective communication/management strategy and clinically effective, patient-focused actions (Figure 1).

1. Patient Requirements

A proportion of patients may be unable to comply with instructions issued by emergency responders. For example, they may be unresponsive, have life-threatening injuries or may not be able to understand instructions or perform activities without accommodations or assistance. In order to maintain operational effectiveness, all patients need to be rapidly categorized to ensure they are on the appropriate treatment pathway. This guidance document defines three patient categories (C1, C2 and C3; Table 1).

Table 1: Definition of patient categories.

Category	Definition
C1	Patients who are able to understand instructions and perform activities without assistance.
C2	Patients who are either unable to understand instructions or unable to perform activities without accommodations or assistance.
C3	Patients who are unresponsive, have life-threatening injuries or require extensive accommodations or assistance.

Allied to defining patient requirements is a decision-making process to determine which patient-focused actions are appropriate and proportionate. Assistance for this form of triage can be obtained using the ASPIRE decision-aiding tool (p25), available from the National Library of Medicine's *CHEMM* website.

2. Communication and Patient Management

Good communication is key to acquiring the trust and cooperation of patients and will maximize the overall efficiency of the initial response phase. Failure to adequately interact with patients may lead to unnecessary anxiety, non-compliance and security issues at the scene of an incident.

3. Patient-Focused Action

The raison d'être of the POR is to save lives and improve the clinical outcome of chemically contaminated patients. In order to achieve this, it is imperative that the following four actions are performed as soon as practically possible:

a. Evacuation

Immediate, orderly movement upwind from hazardous areas is a key component of the initial operational response. Inappropriate or delayed evacuation may exacerbate the clinical effects of exposure to hazardous materials and will hamper the effectiveness of subsequent operations.

b. Disrobe

The critical, urgent need to safely remove contaminated clothing cannot be overemphasized and is a process that requires effective communication to facilitate patient compliance. The golden rule is that no form of decontamination should be undertaken before disrobing.

c. Decontamination

Whilst disrobe will remove the vast majority of a contaminant, exposed areas will require decontamination to remove hazardous material from the hair and skin. There are three forms of decontamination: emergency, gross and technical.

- *Emergency decontamination*, synonymous with "self-care decontamination" as described in the National Planning Guidance (29), is the phrase used to emphasize the time-critical process for the immediate removal of hair or skin contamination by any available means and can be divided into "dry" and "wet".
    - Emergency dry decontamination is the default option and should be performed with any available absorbent material.

- Emergency wet decontamination should only be used when the contaminant is caustic (e.g., provokes immediate skin irritation) or is particulate in nature and should be performed using any immediately available source of water at an appropriate temperature (i.e. not exceeding 40º C or 104º F).

- *Gross decontamination* includes the "Ladder Pipe System", where two fire engines are parallel parked to form a corridor through which patients pass while being sprayed with a high volume of low-pressure water mist. Alternatively, patients can be sprayed directly with hosepipes using a fogging nozzle.

- *Technical* decontamination requires the use of specialist decontamination units and associated resources that need to be transported and subsequently deployed at the scene of an incident. In some jurisdictions, technical decontamination is performed at a hospital and so requires transport of patients from the scene of the incident. Either way, there will be a delay before technical decontamination can be performed.

- Prior instigation of emergency and gross decontamination compensates for the delayed availability of technical decontamination.

It should be noted that the clinical benefits of emergency, gross and technical decontamination are synergistic: such a "Triple Protocol" is most effective when performed as one continuous process (30).

d. Active Drying

The act of drying the skin after any form of wet decontamination is a key step. This simple but effective process is performed to assist removal of contaminants from the hair and skin surfaces and thus prevent further spread of contamination.

Figure 2: Ladder Pipe System decontamination incorporating the provision of towels (identified by arrow in lower left of picture) for post-decontamination drying of patients during a large-scale exercise.

Standard and Non-Ambulatory Response Pathways

Patient-focused actions (evacuation, disrobe, decontamination and active drying) are dependent on patient requirements as defined in Table 1. All C1 patients should be processed via the "Standard" response pathway, with all C3 patients following the "Non-ambulatory" pathway (Figure 3).

Processing of C2 patients will depend on a variety of factors, such as the number of appropriately equipped first responders, the availability of technical decontamination units, and the degree of assistance or accommodations required by each patient. Given the time-critical need to perform patient-focused actions and the fact that the Non-ambulatory pathway is slower and more resource-intensive than the Standard response, C2 patients are initially placed on the Standard pathway until sufficient resources become available for transfer to the Non-ambulatory pathway (Figure 3: dotted line). Subsequent transfers should be performed on the basis of needs or the clinical condition of each C2 patient.

Inclusion of C2 patients within the Standard response pathway will gradually reduce the throughput of all C1 and C2 patients (31). Clearly, this is not an ideal approach but will ensure that all C2 patients receive potentially life-saving treatment during the initial operational response phase.

Standard Response Pathway

The Standard response comprises disrobe, emergency decontamination, gross decontamination and technical decontamination, either with or without limited assistance by first responders wearing appropriate personal protective equipment (PPE). The Standard response has been designed to provide an optimized, high-throughput patient pathway using widely available resources.

Non-Ambulatory Response Pathway

The Non-ambulatory response requires teams of appropriately equipped first responders to provide individualized treatment to patients. The process is the similar to the standard response in that it involves disrobe, emergency decontamination and technical decontamination, but has been adapted to incorporate a greater degree of first responder intervention. Thus, whilst effective, the Non-ambulatory pathway has a relatively low throughput of patients, requires specialist assets and is resource intensive.

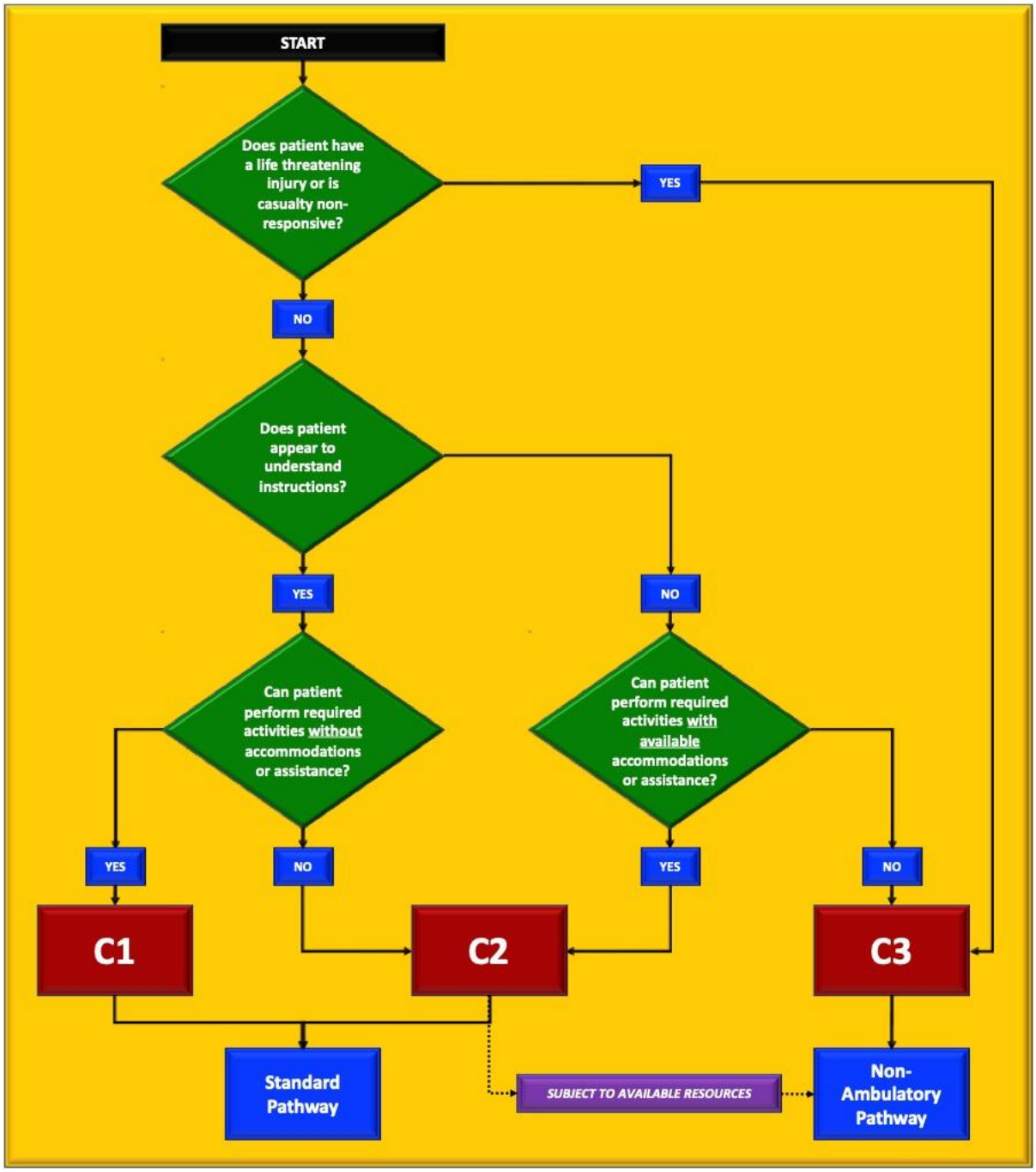

Figure 3: Flow chart for categorization and subsequent response pathway of patients. C1 patients should be able to perform activities (removal of clothing & decontamination) under instruction without assistance. C2 patients should be able to perform activities with accommodations or assistance that can be readily provided at the incident scene. Both C1 and C2 patients undergo the "standard" form of disrobe and decontamination (p 114). C3 patients undergo "non-ambulatory" disrobe and decontamination (p 115).

Patient Requirements

The understanding of patient requirements based on individual needs is one of the three "pillars" that support the POR to ensure all patients receive the best possible treatment at the earliest opportunity. As stated earlier (p19), patients are defined as: those who are able to understand instructions and perform activities without assistance (C1); those who are either unable to understand instructions or unable to perform activities without accommodations or assistance (C2); and those who are unresponsive, have life-threatening injuries, or require extensive accommodations or assistance. (C3). This section will first address the need for patient requirements followed by a focus on requirements for C2 and C3 patients.

Figure 4: Service animal accompanying an individual who is blind through a Ladder Pipe System decontamination corridor during a large-scale exercise ("Operation Downpour") performed at the University of Rhode Island, August 2017.

Decision-Aiding Tool (ASPIRE)

The need to perform wet decontamination on patients during a chemical incident as part of the specialist operational response is not a foregone conclusion. For example, highly volatile liquids can be rapidly lost from the skin surface by off-gassing and so disrobing alone may be a proportionate response. As gross and technical decontamination are associated with the risk of hypothermia (37, 39, 40, 53, 54, 66, 83-88), wet decontamination should not be considered an automatic response to chemical contamination.

The initial decision to perform wet decontamination has been described as "decontamination triage" (36). The need to establish a proportional response has previously been acknowledged and algorithms based on visual indicators of patient status have been developed to help incident commanders identify appropriate actions (39). It should be noted that the absence of signs or symptoms of exposure to toxic chemicals is not a reliable triage indicator, particularly for chemicals that undergo relatively slow dermal absorption (e.g., nerve agents such as VX) or have a delayed onset of action (e.g., sulfur mustard).

The need for wet decontamination of patients will primarily be dictated by the volatility of a chemical. For example, volatile substances such as ether or benzene rapidly evaporate from the skin surface and so decontamination is unlikely to provide any clinical benefit by the time an LPS corridor has been set up. In fact, application of water to the skin surface may actually impede evaporation and result in enhanced dermal absorption. In contrast, non-volatile materials such as the nerve agent VX will not evaporate from the skin surface and so wet decontamination will be a critical response process.

Recent studies (15, 16, 24) have demonstrated (Figure 5) that the evaporative loss of a chemical from skin and clothed surfaces can be predicted using latent heat of vaporization (ΔH_{evap}), a well-defined physicochemical property. This has facilitated development of the decision-aiding tool "ASPIRE" (Algorithm Suggesting Proportionate Incident Response Engagement), available on National Library of Medicine's on-line "*CHEMM*" system (89).

The ASPIRE model requires two user inputs: the identity of the chemical and the time that has elapsed since exposure. If the identity of the chemical is unknown, then an estimate of volatility can be input by the end user via a visual interface tool. These input parameters are used to estimate the residual amount of contamination on skin and clothing, which provides an objective basis for deciding whether to proceed with disrobe and wet decontamination.

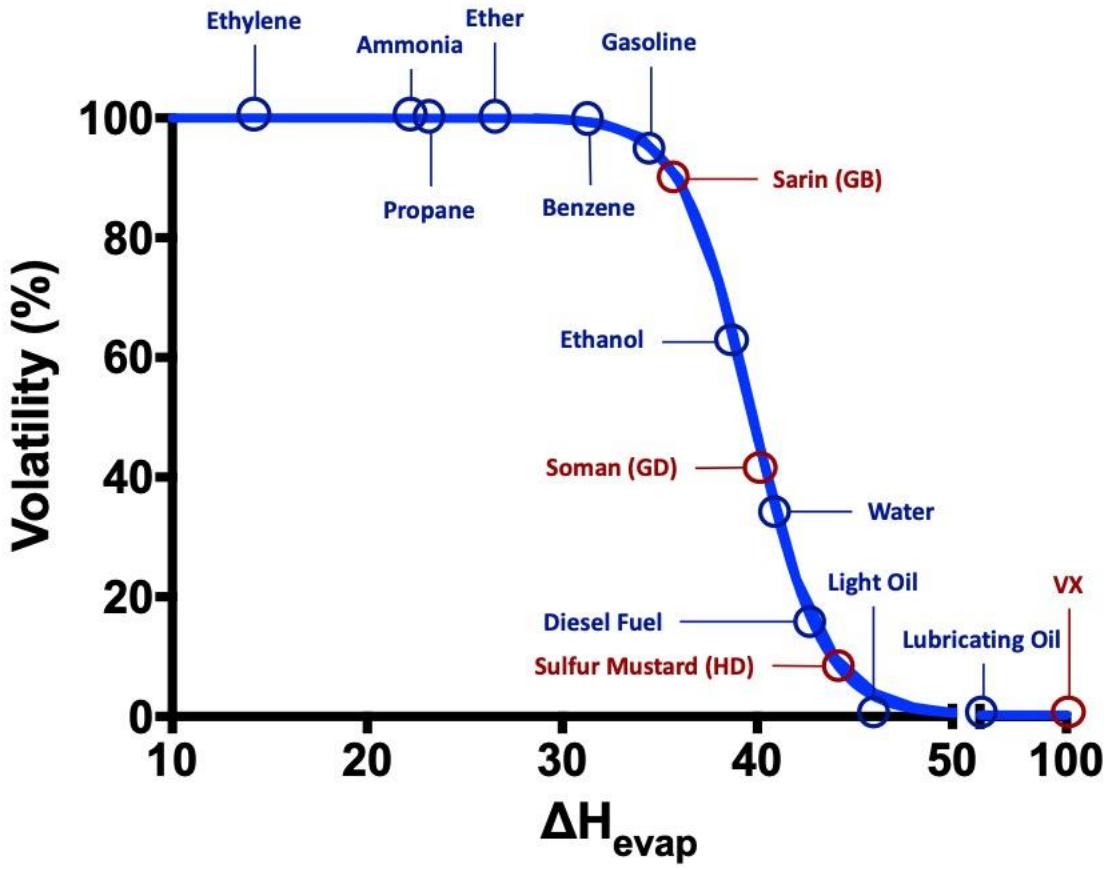

Figure 5: Relationship between latent heat of vaporization (ΔH_{evap}, expressed as kJ mol^{-1}) and volatility of a chemical, expressed as percentage evaporative loss one hour after skin surface contact (30ºC). A selection of common substances and chemical warfare agents have been superimposed to provide a practical context. Volatile materials (ΔH_{evap} < 30 kJ mol^{-1}) are likely to evaporate from the skin surface before a functional LPS corridor can be established. Conversely, less volatile substances (ΔH_{evap} > 50 kJ mol^{-1}) will remain on skin and so wet decontamination will be effective. Chemicals with a ΔH_{evap} between 30 and 50 have intermediate volatility; hence, the need for wet decontamination will be dictated by the time elapsed since exposure.

Should first responders not have immediate access to the on-line version of ASPIRE, it is possible to confirm the need for wet decontamination using a "ready reckoner" (Figure 6). Clearly, if patients are showing signs or symptoms of exposure then disrobe and decontamination should be performed without delay.

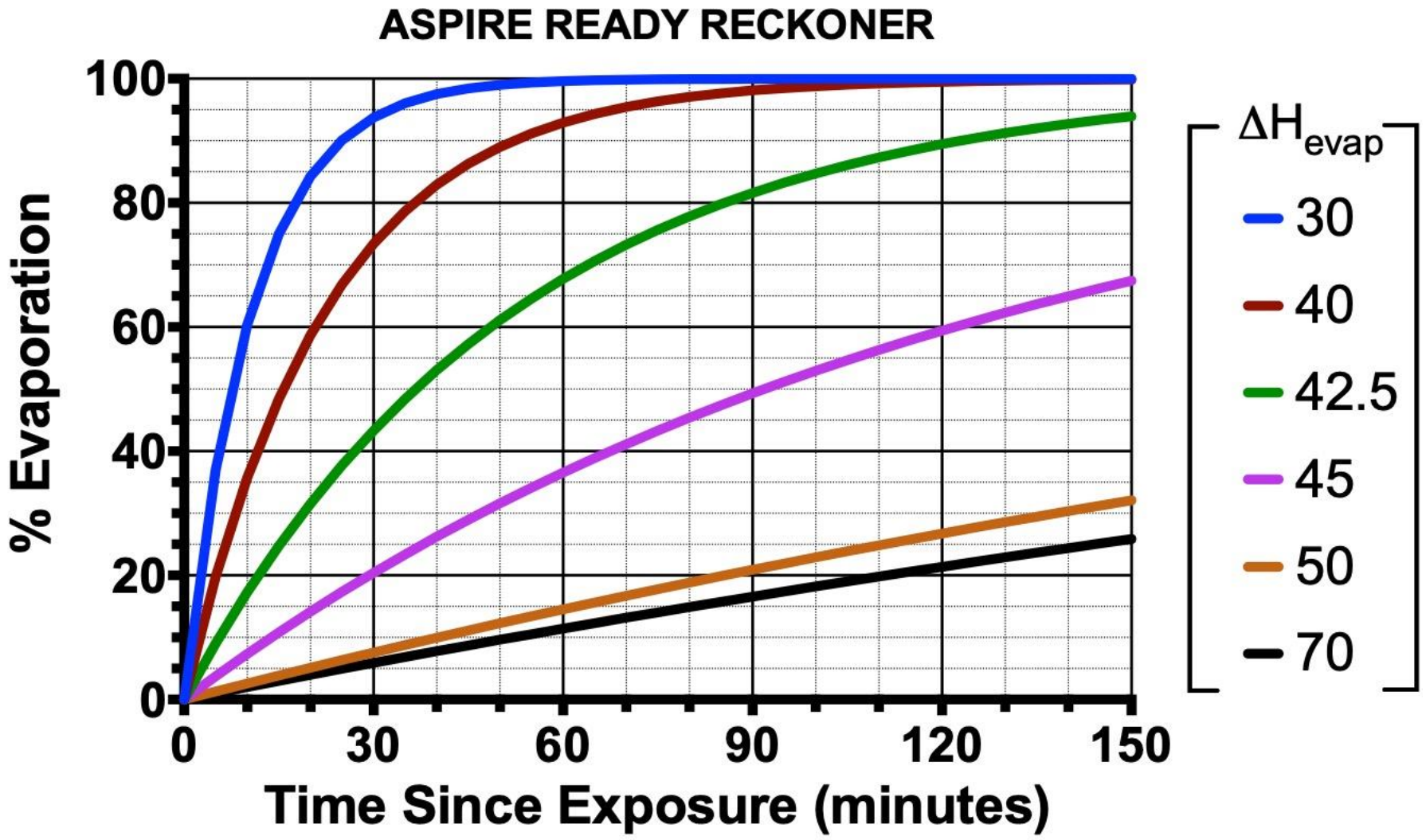

***Figure 6:** Aspire "Ready Reckoner" chart to assist decision to proceed with wet decontamination by incident commanders. The values presented on this chart are conservative in that they underestimate the evaporative loss of volatile chemicals; this safety feature has been incorporated into the model to ensure that wet decontamination is the recommended course of action for any borderline cases.*

ASPIRE "Ready Reckoner" Instructions

The following instructions provide guidance for use of the ready reckoner. A worked example is given in Table 2. If the contaminant is unknown or not listed in Annex A then proceed with decontamination as a default option.

1. Identify the chemical contaminant.
2. Use the lookup table (Annex A) to determine the latent heat of vaporization (ΔH_{evap}) of the contaminant.
3. Pick the line on the graph (Figure 6) that has the next highest ΔH_{evap} value.
4. On the horizontal (bottom) axis of the graph, find the point corresponding to the time that has elapsed since exposure to the contaminant. Follow the line from that point up the graph until it intersects the relevant ΔH_{evap} line and read off the corresponding percentage evaporation value from the vertical axis on the left.
5. If the percentage evaporation value is close to 100% and patients are showing no signs or symptoms of exposure, wet decontamination is not necessary.

Table 2: Worked example for use of ASPIRE Ready Reckoner.

Step	Narrative
1	Patients present at the scene of an incident have been sprayed with liquid from a hijacked road trailer. The (GSH) signage on the trailer identifies the chemical as acrolein.
2	Acrolein is listed in PRISM Annex A with a corresponding ΔH_{evap} value of 29.6 kJ mol^{-1}.
3	The next highest value of ΔH_{evap} on the ready reckoner chart is 30 – indicated by the blue line.
4	The incident occurred at 1415h. The time is now 1545h, so 90 minutes have elapsed since exposure. Look up the value of 90 minutes on the horizontal (bottom) axis of the ready reckoner and follow this up the chart until you reach the blue line. Now go to the left of this point towards the vertical axis. This gives a % Evaporation value of 100%.
5	All of the chemical is expected to have evaporated from the skin surface and so wet decontamination will not be necessary.

Patient Prioritization: Ethical Considerations

The principle of prioritizing patients during a disaster can be dated back to when the Egyptians conceptualized "*ma'at",* meaning the good order of society (32). During a mass patient incident, prioritization is typically based on "the greatest good for the greatest number" (33). However, this utilitarian approach does not delineate between lives saved or years-of-life saved. Another concept used by first responders is based on deontology: an ethical approach in which the responder's actions have precedence over the consequences (34). An additional consideration for chemical incidents involves the values and rights of the individual, recognizing that there is no "one size fits all" solution (35).

Current guidelines identify the young and elderly, individuals with chronic health conditions and pregnant women as priorities during a chemical incident (29, 36, 37). However, there is no definitive, hierarchical list and in practical terms, first responders will ultimately be responsible for determining patient prioritization *in situ*, as other factors (such as clinical needs of patients, situational awareness, resource availability, scale of incident, dynamic risk assessment, etc.) will also need to be considered.

Category 2 Patients

C2 patients include individuals with physical, sensory and cognitive disabilities or chronic health conditions, the elderly, children, pregnant women, and those whose primary language is not English or have Limited English Proficiency (5, 29, 37-43). Implementation of the POR is based on a substantial body of recent scientific evidence that includes human volunteer studies in which quantitative methodologies have been used to measure decontamination outcomes (6, 8, 9, 11, 12, 23, 25, 28, 30). Such studies have focused on C1 patients. Other exercises have also been performed to assess the practicalities involved in the decontamination of individuals with disabilities (44, 45). However, such investigations did not include objective measures of decontamination efficacy and so there remains a lack of evidence-based, clinically-optimized protocols for C2 patient decontamination. Correspondingly, attempts have been made to adapt current procedures primarily designed for C1 patients to meet the requirements of others (25, 30). This is not an equitable nor a practical approach and highlights the need for further research to ensure equal access to rapid and effective treatment for the whole community (29, 46).

Patients with Disabilities

It is estimated that adults and children with disabilities represent ~20% of the US population (47). There is ample evidence to demonstrate additional incident response requirements for patients who have physical, sensory and cognitive disabilities (29, 37, 39, 42, 44). Therefore, understanding and integrating the needs of this population will be essential in the development

and optimization of procedures. Although first responders lack evidence-based guidance on addressing patient requirements for individuals with disabilities, attempts have been made to adapt current practices for C2 patients as demonstrated in the following strategies.

Evacuation

The initial contact between first responders and patients with disabilities may occur at evacuation, which aims to reduce exposure and improve outcomes by moving patients to a safe distance (48). During evacuation, some patients with disabilities may need assistance from appropriately protected first responders to move away from a hazardous area and others will need accessible communications to understand instructions. Since the needs of patients with disabilities may not be evident, first responders should immediately ask patients if they require assistance to evacuate (29, 44, 45, 49).

Disrobe

There is a considerable body of evidence supporting the critical need to disrobe as soon as possible after evacuation (29, 36, 50-54). The ability of some C2 patients to perform immediate disrobe may be impacted by their need for accommodations or assistance. For example, patients who have visual disabilities may encounter challenges completing disrobe because of their lack of familiarity with the environment and surroundings (41). Also, current procedures do not take into consideration individuals who use equipment or devices to assist with daily activities such as undressing. The lack of adaptive equipment or assistive devices can present significant barriers to disrobing for patients with motor (e.g., dexterity, balance), sensory (e.g., perceptual) and cognitive (e.g., planning, reasoning) disabilities (25, 30).

Decontamination

There are a range of recommendations for decontaminating patients with disabilities. For example, patients who are unable to ambulate or require durable medical equipment (DME; e.g., wheelchairs, walkers, canes) could be placed on backboards or roller systems (29, 41, 45). As noted earlier (p22), this process will become time- and resource-intensive (29). Plastic chairs have been suggested as an alternative (41, 44, 55) but are associated with substantial practical issues that could affect the safety of patients (44, 56). Further technical research is required in this area (41) and the lack of guidance presents barriers to equal access, safety and effective decontamination procedures for patients with physical disabilities (25, 30).

Patients with sensory disabilities may also have additional requirements. For example, those who have visual disabilities may encounter challenges that will impact on their ability to independently follow procedures and the decontamination route (12, 55). Other patients who are deaf or hard of hearing may have difficulty communicating with responders (25, 31, 44). A

further, important consideration for first responders is that PPE may significantly degrade the clarity of verbal and non-verbal communication (25, 30, 44).

Patients who have cognitive disabilities may have reduced attention, processing speed and memory and so may require increased assistance during decontamination (5, 41). The stressful environment of an incident may further intensify the impact for some patients, such as those who have autism, resulting in the potential for increased anxiety, sensory sensitivities and possible aggressive behaviors.

Service Animals and Ancillary Items

It has previously been suggested that service animals should be muzzled and decontaminated using moist towelettes (37), in an area or corridor where people are not being decontaminated (57), by responders who are specifically trained in animal triage (29). The consequences of a non-specific protocol for service animals and their handlers were demonstrated at a recent exercise that resulted in C2 patients expressing a low level of confidence in the outcome of decontamination and first responders identifying the need for more effective communication strategies and additional personnel (25, 30). Furthermore, the lack of guidance on decontamination of ancillary equipment resulted in ancillary items such as harnesses not being decontaminated (25, 30). Patients with disabilities who use durable medical and ancillary equipment encounter additional challenges, which are reviewed in more detail below (p35).

Communication

In order to effectively communicate with patients who have disabilities, information should be provided in audible, text and picture formats, reinforced with body language (41). First responders should use large and clearly marked signage (44), pictogram instructions (29) and communicate calmly while expressing empathy to provide reassurance, especially for patients who have cognitive disabilities (58).

Elderly Patients

Patients who are 65 or older are traditionally considered elderly and ~40% of this population have one or more disability (59). Based on the increased risk of chronic health condition or disability, older adults may require assistance during evacuation, disrobe, decontamination and active drying (41). Elderly patients have been identified as having a higher risk of mortality, increased sensitivity to toxic chemicals and secondary complications from incidents (60, 61). As a result, the elderly population has been identified as a priority for decontamination (29, 36), although there are no specific guidelines available. Ethical principles (p29) should be considered when prioritizing elderly patients, particularly the balance between years of life saved and the number of lives saved.

Patients with Chronic Health Conditions

Chronic health conditions affect ~60% of the US adult population (64). Since some patients with chronic conditions are more susceptible to the effects of contamination, this population is considered a priority (29). Although there is minimal guidance specific to the management of patients with chronic illnesses, first responders should take into consideration the potential comorbidity of chronic illnesses with increasing age and in those who have disabilities. For example, chronic conditions impacting mobility, such as arthritis or a stroke, may result in a need for assistance to evacuate, disrobe and independently conduct decontamination actions (63). Some patients may have chronic conditions (e.g., certain forms of asthma) that will be adversely affected by exposure to cold water during LPS decontamination and so will need to be kept warm. In some instances, patients with chronic conditions may need access to medications or the use of durable medical and ancillary equipment (e.g., oxygen, ventilators, diabetes pump) which are crucial to maintaining their health (41).

Children

Children (18 years or under) represent ~24 percent of the US population (65). The considerations for children in planning for a chemical incident have been broadly established (29, 37-39, 66). Given their anatomical, physiological and developmental characteristics, combined with the anticipated years of life saved, it is recommended that children be considered a priority (29, 36, 61, 67-70). A policy statement from the American Academy of Pediatrics indicates that there are major gaps in the development and implementation of medical countermeasures, which are mainly tested and evaluated in adults (69). There is minimal evidence-based research on patient-focused actions for the child population.

Evacuation

It has been well established that the psychological needs of children should be considered and every effort made to keep them with their families, under the supervision of and with assistance (where necessary) from emergency responders (29, 37, 55, 66, 68, 71). In addition, the use of PPE may increase their anxiety, since evacuation may be the first interaction the child has with a first responder whose face may not be obscured by a respirator or face mask (71).

Disrobe

It has been documented that children may be hesitant to disrobe in the presence of strangers: even if a parent is present, it may take extra time to disrobe an uncooperative child. It is recommended that first responders of the same gender assist with the process and, if possible, that children be grouped based on gender (71). The issue of privacy is reviewed in more detail below (p62).

Decontamination

During decontamination, parents may struggle to decontaminate themselves and their children at the same time, especially those under 2 years of age, who are especially difficult to hold when wet. The process is even more challenging for first responders wearing PPE, because it affects their ability to hold a child, and multiple responders may be required to wash a young patient (66). It is recommended that children who are not old enough to walk should be placed on a stretcher and carried by first responders. Additional options include caregivers along with first responders carrying the young patients in a laundry basket or baby bath (37).

Infants and young children are more susceptible to cold or heat injuries and have a greater predisposition to hypothermia (29, 41, 46, 66, 71, 72). Therefore, warm water should be utilized wherever possible (41, 55, 66, 68) and provision for adapters with hand-held sprayers should be available (66, 71). Given the concerns about hypothermia, foil blankets, heaters and additional towels and blankets should be available (37, 66, 71). Children should then be moved quickly to a post-decontamination area to be monitored (66, 71). When young children enter a shower corridor, they may become slow moving or distracted, impeding the flow of patients; they thus require supervision and assistance (106). Also, children who are unaccompanied will require a dedicated emergency responder throughout the process (66, 68, 72).

Communication

Communication with children poses challenges for first responders, including the initial screening of young children, because they may have difficulty communicating symptoms (71). Recommendations include making eye contact and explaining clearly what is happening, with use of cartoons, posters, videos and pictographic instructions (29, 37) if available.

Pregnant Patients

Pregnant patients have been identified as a priority for decontamination, since both the woman and her unborn child(ren) may be susceptible to adverse health effects caused by exposure to toxic substances (29, 41, 61, 73, 74). If a pregnant woman has a disability, additional chronic health conditions, or needs assistance with communication, an assumption would be made that C2 patient actions would be implemented. Current recommendations are primarily based on the potential impact of a chemical exposure on the fetus.

During the initial action of evacuation, if a woman is not visibly pregnant to emergency responders then they will be unaware of the increased risks. Therefore, first responders should ask females of child-bearing age if they may be pregnant (41). Once a woman is identified as being pregnant, emergency responders should provide information on how decontamination and antidotes might affect the fetus, if such data is available. It should be noted that an incident requiring decontamination will likely cause an increase in stress for pregnant women and anxiety over the safety of their unborn child (5).

Gaps have previously been identified in guidelines for the most effective methods of decontaminating pregnant women (29, 46). However, there is no overt reason to question the effectiveness of the revised (Triple Protocol) decontamination in this population, although confirmatory studies are required.

Non-English-Speaking Patients

Patients whose primary language is not English or who have Limited English Proficiency (LEP) may encounter challenges with communication at all stages of the Initial and Specialist Operational Response (29, 37). For example, patients are likely to experience difficulty in understanding and following instructions, which may result in confusion and misunderstanding and delay the process of decontamination (41, 75, 76). This is particularly relevant to emergency dry decontamination, where a poor understanding of instructions may reduce effectiveness (30, 77, 78).

Several documents provide recommendations for improving communication during decontamination for this population, including the provision of instructions in multiple languages, the most commonly used languages within a population and picture format (29, 37). The provision of interpreters as part of the decontamination team has been considered as a strategy to enhance effective communications (29, 44). In one study, a separate line for groups of people who speak the same language was implemented along with multiple interpreters. However, these were found to require additional personnel and would not be feasible for mass patient decontamination (44).

There is a need for additional work to develop unified strategies to ensure patients whose primary language is not English or who have LEP receive critical, accessible, and understandable communications at the same time as other patients.

Durable Medical Equipment

Adults and children with disabilities, chronic health conditions and the elderly may use DME. There is ample guidance recommending that decontamination plans consider patients who use such equipment (29, 37, 38, 41, 45, 49, 55, 57). However, these recommendations are not evidence-based and so do not provide definitive guidance (Table 3). In a recent large-scale exercise, patients with DME introduced significant operational challenges for first responders, which had adverse outcomes and further emphasized the need to establish and evaluate relevant guidelines for durable medical and ancillary equipment (25, 30).

Previous guidance on DME has been neither definitive nor consensual (Table 3). This reflects the lack of scientific evidence on the amenability to decontamination of a wide range of items and contaminants that may be encountered during an incident. Regardless of the process utilized, patients should be informed in advance how their items will be handled in order to improve compliance (29).

There have been suggestions that patients who use DME should be separated into their own line. For example, any patient who uses DME would be processed with C3 patients, or a

separate line should be established to process those who specifically have mobility disabilities requiring equipment (55). Clearly, this could have substantial resource implications and so may not be appropriate until sufficient first responders and equipment become available.

Table 3: Previous recommendations for retention, decontamination or removal of durable medical equipment and ancillary items.

Item(s)	Recommendation
Prosthetics, hearing aids and eye glasses.	To be retained by the patient during decontamination (4, 29, 37, 38, 41, 45).
Hearing aids, electrical wheelchairs, assistive technology devices, ventilators, foam, cushions and leather components.	Not amenable to decontamination and should be removed (37, 41, 55).
Eye glasses, canes, wheelchairs (without cushioned parts), prosthetic limbs (without leather components), walkers, canes and crutches (without foam or cushioned parts).	Remove from patient, decontaminate separately then return to patient (37, 41, 55, 71).
Hearing aids, insulin pumps and ventilators.	Visually inspect for solid or foreign bodies and return to patient for decontamination if not overtly contaminated.
Hearing aids and eye glasses.	Remove, cleanse and return to patients prior to decontamination (49, 55)
	Leave *in situ* and cleanse during decontamination (37)
	Remove and cleanse while patient undergoes decontamination, keeping hearing aids on whenever possible (29, 41).

Service Personnel Requirements

It has been established that there is a clear need for additional first responders to assist C2 patients during evacuation, disrobing, decontamination and active drying (29, 40, 41, 55, 66, 68, 72, 79). First responders agree that this population requires assistance, but have expressed concerns regarding the availability of personnel and resources (30). To address these shortfalls, the implementation of a "buddy system" has been suggested (29, 40, 41, 79, 80). However, the degree to which C2 patients wish to be partnered with other patients instead of qualified first responders has recently been questioned, with patients stating that this approach was

"inappropriate", "disrespectful" and that first responders were "tasking others to do their jobs" (25, 31). Moreover, the concept of grouping similar patients was interpreted as a deliberate separation of populations, which resulted in patients feeling "left behind" and being the last to be processed through decontamination (25, 31). Clearly, further work is required to identify strategies to balance C2 patient requirements with the availability of first responder personnel.

Issues

It is evident that there is a lack of guidance to address meaningful access to planning and procedures for evacuation, disrobe, decontamination and active drying for C2 populations. Therefore, there is a clear requirement to generate evidence-based decontamination guidance and protocols for treating patients, including those with disabilities, the elderly and those with chronic health conditions (25, 29, 31). The current decontamination procedures lack technical evidence and are based on perceived best practices, relying on an assumption that the needs of C2 patients can be met by ambulant patient protocols. In addition, the lack of guidance on the treatment of pregnant women and children requires additional work to identify strategies to optimize the process and outcomes for these populations (29).

Reducing the delay between initial exposure to a contaminant and subsequent emergency response actions is considered one of the most important factors for determining the number of lives saved and severity of effects in survivors (7, 9, 10). Recent evidence suggests the presentation of C2 patients will either have a detrimental effect on the operational effectiveness of established incident response procedures or will result in their receiving treatment later than other patients. For example, research has provided evidence that the movement of C2 patients through emergency dry and LPS decontamination is 3 to 11 times slower than that of C1 patients (25, 30). This delay may consequently have a negative impact on all patients in terms of clinical and operational effectiveness and clearly highlights the need to develop more effective incident response protocols for C2 patients.

The use of DME must be considered in decontamination planning. As noted previously, the findings from a large-scale exercise demonstrated the significant impact of a lack of authoritative guidance or consensus on the decontamination of DME, ancillary items and service animals. The current default approaches impose substantial logistical challenges for first responders and impact the ability of patients to maintain their independence (25, 30). As a result, further research, including laboratory studies, is needed to evaluate and establish protocols for the decontamination of non-human components (DME, ancillary items and service animals).

It has been established that there is a requirement to increase the number of first responders supporting the initial and specialist operational response to meet the requirements of C2

patients. Further work is required to review decontamination staffing levels and more effective strategies to provide a sufficient number of first responders to meet the needs of C2 patients.

Although all verbal and written information should be provided in multiple formats, including audible, text, picture and multiple languages throughout the patient actions, there continue to be barriers to the communication of effective, accessible and timely information. This suggests that improvements in communication are essential for first responders to more effectively manage the process to meet patient requirements in an optimal manner. The development and implementation of effective communication strategies should be addressed during the planning process.

Figure 7: Active drying, following Ladder Pipe System decontamination performed by a C2 patient during a large-scale exercise ("Operation Downpour") performed at the University of Rhode Island, August 2017.

Category 3 Patients

The initial and specialist operational response to individuals who are unresponsive, have life-threatening injuries or require extensive assistance (C3 patients) has received only minimal attention: there are a number of significant knowledge gaps in current protocols for the evacuation, disrobe, decontamination and active drying of C3 patients and so only limited guidance is available for this patient population.

Prioritization

There is a lack of evidence concerning the risk assessment and decontamination triage of C3 patients (29, 46, 52). Available guidelines address patients' vital signs and symptoms as part of the prioritization process and identify patients who are breathing, conscious and can follow instructions but who are non-ambulatory as a high priority for evacuation (36).

Patient-Focused Actions

The evacuation of patients may present challenges regardless of whether their condition is directly related to the incident or represents a pre-existing disability. Patients with life-threatening injuries may need to be stabilized before they are moved. However, if the hot zone is clearly life-threatening, evacuation must take precedence over stabilization: in such cases, a "snatch rescue" (81) may be considered before specialized resources arrive (29, 46, 50, 51, 61); (p49). Rescuers will need appropriate PPE to avoid becoming patients themselves. Since the principle role of first responders is to save lives, difficult decisions will need to be taken if visibly distressed C3 patients are encountered in the hot zone during the initial operational response.

Disrobing has been identified as highly effective (p51) and should be completed as soon as practically possible (3, 8, 29, 36, 50, 53, 54, 62, 82). Emergency medical service (EMS) personnel generally have good access to disrobing items, including cutting tools for clothing ("trauma shears") and aluminum foil blankets ("space blankets") to address privacy issues (50). Garments should be cut from the patient to minimize the spread of contaminant (51, 54) as outlined later (62).

A potentially life-saving objective of the initial operational response is to complete disrobe and emergency decontamination as soon as practically possible and there is a considerable body of evidence to support the clinical management of C1 and, to a lesser extent, C2 patients. However, until recently there have been no scientific evaluations of C3 decontamination protocols and so previous guidance has been predicated on "perceived best practice". Prior recommendations include the use of specialized equipment such as backboards, roller systems and gurneys to transport patients (29) and multiple LPS deployments to facilitate parallel

processing of patients (36). However, the latter will be limited by the availability of local resources and so may be impractical in rural or less densely populated locations.

A recent study reported an evidence-based procedure for C3 disrobe and emergency dry decontamination (52). The protocol was designed to accommodate the requirements of patients with severe injuries and so incorporates such aspects of good clinical practice as airway and spinal injury management. The process can be performed in three minutes and provides a C3 patient with the equivalent of the standard IOR. The same study also identified a four-minute wet decontamination process for subsequent technical decontamination. Both protocols are described in detail later (p78 and p104, respectively). However, these putatively optimized protocols have yet to be evaluated in a realistic environment and further work is required to assess their robustness and clinical efficacy under operational conditions.

Following disrobe, emergency decontamination and technical decontamination, all patients who are unresponsive or have life-threatening injuries should be transferred directly to a hospital or medical facility for advanced medical treatment (51).

Issues

A key operational consideration is the safety of first responders. In order to adequately address safety concerns, further work is required to determine the best protocols for evacuation of C3 patients from a hot zone in order to eliminate, or reduce to acceptable levels, the risk of exposure to toxic chemicals. In particular, it is critical to develop adequate risk assessments to ensure the safety of first responders performing disrobe and emergency dry decontamination on C3 patients.

Although limited research has been reported on disrobe, emergency dry decontamination and technical decontamination of C3 patients, additional studies are required to assess the combined effectiveness of dry and wet decontamination under more realistic conditions and to develop procedures to ensure the safety of first responders. The resource-intensive treatment of C3 patients also necessitates a reappraisal of first responder staffing levels required to meet the needs of such patients, particularly during the IOR phase.

PATIENT REQUIREMENTS

Immediate Actions

- Identify & categorize patient requirements (C1, C2 or C3) as soon as practically possible.
- Ask individuals if they require assistance to complete patient-focused actions.
- Do not delay C1 or C2 patient-focused actions while awaiting arrival of specialist resources.
- Establish a non-ambulatory pathway for C3 patients as soon as practically possible.
- Use the on-line ASPIRE decision-aiding tool or "Ready-Reckoner" to establish appropriate and proportionate patient-focused actions before committing to LPS or Technical decontamination

Key Points

- Good communication (verbal, signage or body language) is particularly important for instructing and reassuring C2 patients.
- Provide adequate response personnel to address patient requirements.
- Families should undergo patient-focused actions together wherever possible.
- Everyone who is affected by the incident should have the right to receive accessible, inclusive, and equitable patient-focused actions.

Communication and Patient Management

An effective communication strategy is one of the three "pillars" that support the POR to ensure all patients receive the best possible treatment at the earliest opportunity. First responders should take steps to provide meaningful access and effective communication at all times and with all patients.

Effective communication with patients is vital to any incident requiring mass patient decontamination (90, 91). As stated earlier, patients who may need additional communication considerations include individuals with disabilities, children, the elderly and those whose primary language is not English or have LEP.

Although there is ample evidence supporting the physical and technical aspects of decontamination, there is a lack of evidence-based guidance addressing strategies for effective and accessible communication of evacuation, disrobing, decontamination and active drying procedures. Moreover, the communication and patient management strategies identified in current guidance documents have not been evaluated sufficiently to determine their level of effectiveness in an incident (79).

Communicating During the Initial Operational Response

First responders should immediately foster an element of trust with patients, utilizing credible and respected sources to provide relevant information (29, 37). Establishing an immediate foundation of trust and credibility should improve patient compliance and outcomes (91, 92).

It is important for first responders to communicate as quickly as possible what is known about the incident, what actions are in place to assist those impacted, how to help themselves, why decontamination is necessary and what should be expected during the disrobe and decontamination processes (29, 37, 54). Also, patients need to understand the steps required to complete such patient actions and their presumed degree of effectiveness (92). In addition, it has been recommended that patients be informed of potential adverse health effects to themselves and others if decontamination is not completed (29).

Communication Strategies

Based on the limited availability of evidence, there are four aspects for promoting effective patient communication (Table 4):

Table 4: Basic Communication Strategy.

Identify Populations	• Identify patients who may need support for communicating, such as individuals with disabilities, the elderly, those whose primary language is not English or have LEP, and children.
What Information?	• Why decontamination is necessary. • What patient-focused actions to expect. • How to perform patient-focused actions. • Benefits of decontamination. • Implications of not cooperating; adverse health effects on self, family and other patients. • Accommodations and assistance available.
How to Communicate	• Pictorial instructions. • Pre-recorded audio or video messages. • Multiple formats of materials (e.g., audible, text, video, pictures, large print). • Languages (prevalent in area). • Body language or gestures. • Debriefing sessions with groups of patients following the primary operational response.
Planning Considerations	• Identify strategies for access to interpreters for persons whose primary language is not English, who have LEP, or are deaf or hard of hearing. • Translate printed materials into other languages (commonly spoken), Braille, large print. • Identify auxiliary aids and services to ensure effective communication. • Identify bilingual resources.

Disrobing

During disrobing, patients should be provided with a clear direction on how to safely disrobe and what the expected outcomes will be in terms of a significant, potentially life-saving reduction in contamination (37). In situations where patients are resistant to disrobing, supplementary information may promote compliance (93).

Decontamination

Communication challenges during decontamination include the need for clear instruction and explanation of procedures. For example, a recent study identified the potential importance of using a communication strategy involving both health-focused and practical information on decontamination (93). In addition, difficulties communicating with emergency responders (associated with the use of PPE) may result in patients feeling frustrated (37). Strategies to address the barriers of using PPE include devices that enhance or amplify voice communication, radio headset systems and increased use of hand signals (37). However, these recommendations have not been evaluated in practice and thus further research is required.

Good communication throughout the decontamination process is important to enhance patient compliance (29, 54). Patients may have natural feelings of anxiety and panic during an incident and so it has been suggested that first responders provide authoritative guidance in a simple, calming manner to enhance understanding, decrease anxiety and encourage compliance (29, 37). A review of previous exercises has confirmed good communication as a key factor for enhancing patient compliance and confidence in the effectiveness of decontamination (91).

Issues

A range of communication strategies have been identified but there remains a need to evaluate such guidance under exercise conditions in order to develop a standardized communication strategy. There is also a lack of evidence-based guidance to address meaningful access and effective communication to meet the diverse communication needs of the whole community.

COMMUNICATION & PATIENT MANAGEMENT

Planning

- Prepare pre-recorded or pre-scripted messages.
- Develop pictograms for use during incidents.
- Consider how communication can be best achieved within your community.

Key Messages

- Patients need to cooperate with first responders in order to get the best possible care.
- Cooperation will not just benefit the affected individuals: it will prevent family, friends and the local community from being affected.
- Explain that patients who do not cooperate will put others' lives at risk.

How to Communicate

- Be open and honest about what is known about the incident and what actions are being taken to resolve the situation.
- Use loudspeakers if available.
- Practical demonstrations and/or body gestures may be useful for explaining disrobe and decontamination stages.
- Provide pictorial instructions if available.

Patient-Focused Actions

Evacuation

Following recognition of a chemical incident, evacuation to a safe distance should be considered a priority action to reduce exposure and improve patient outcomes (48). However, this is not necessarily the default option: shelter-in-place should be considered if evacuation risks further significant exposure (94, 95) or there is a threat of secondary devices or other significant hazards.

The majority of current guidance documents identify evacuation as an essential part of the incident response process, stating that evacuation should be in a direction upwind and uphill from the hot zone and that only responders who are wearing appropriate PPE should attempt to enter the hot zone to assist in the evacuation (29, 36, 54, 84, 85, 96). Patients who leave the scene through their own efforts and without supervision (self-evacuation) may pose a health risk to the wider community and to healthcare facilities from the uncontrolled spreading of contamination (29). It is conceivable that disrobing, (performed as part of the emergency decontamination procedure) may limit the extent to which individuals feel compelled to leave the scene of an incident; there should be no intentional delay in proceeding from evacuation to the disrobe and emergency decontamination phases.

Zoning

Evacuation of patients from the point of contamination represents the first phase of "zoning", which characterizes the level of contamination within different areas of the incident response (Figure 8). These are commonly referred to as the "hot" (or "exclusion"), "warm" and "cold" zones (51, 97).

The hot zone includes the point of release and so will contain the largest amounts and/or airborne concentrations of the contaminant. The amount of contaminant in the warm zone will be substantially lower, although discarded clothing and decontamination waste may result in localized "hot spots" of contamination. The concentration or amount of contaminant in the cold zone should be nominally zero, thus providing a working environment that does not require first responders to wear PPE.

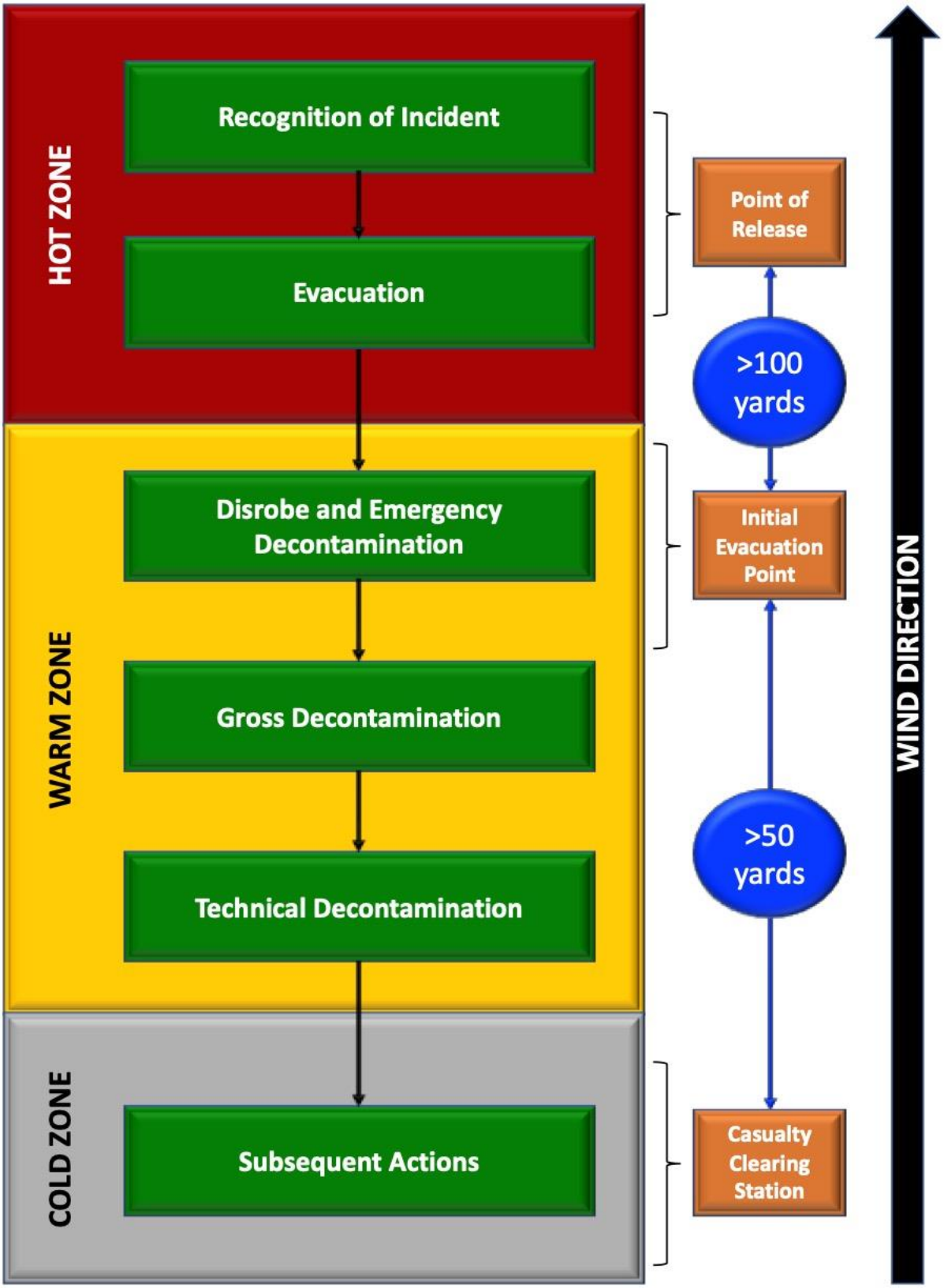

Figure 8: Incident response zones, with <u>minimum</u> distances between a liquid contaminant ("point of release"), point of disrobe and emergency decontamination ("initial evacuation point") and safe area ("patient clearing station"). The flow of patients should be against the prevailing wind direction and, ideally, in the direction of higher terrain.

Communication

Evacuation may represent the initial point of contact between first responders and patients. As such, this will be an opportunity for first responders to take control and manage the incident by gaining the trust and cooperation of patients through good communication. Effective communication strategies developed for decontamination (93, 98) can be applied to the management of evacuation. In this context, clear and practical instructions are essential in order to maximize the health benefits (see Communication and Patient Management; p42).

Safe Distances

Guidance documents do not generally stipulate a safe distance for evacuation, as it will be dependent on a number of factors, such as the physicochemical properties and toxicity of the contaminant, meteorological conditions, terrain and the amount of contaminant present (95). However, lookup tables can be used if the identity of the contaminant is known: such authoritative sources include "ERG-2016" (99) and the National Library of Medicine's on-line "*WISER*" system (89). The evacuation point should not be any further from the point of contamination than necessary, as longer distances will impact operational effectiveness by reducing the speed at which patients can be evacuated and will increase the physiological burden on first responders wearing PPE when moving between the hot and warm zones.

Clinical Treatment

In the past, patients might not have received life-saving treatment until completion of evacuation and/or decontamination (50, 51). Any such delay in treatment could compromise the survival of patients after a hazardous material incident, especially those with life-threatening injuries. For this reason, advanced clinical interventions, such as endotracheal intubation, intra-osseous antidote administration and hemostatic procedures, are becoming increasingly common practice within the hot and warm zones (51, 100, 101), although these require advanced training and the availability of appropriate protective equipment (102).

Impact of Patient Requirements

All C1 patients should be able to self-evacuate from the hot zone under the direction of first responders wearing appropriate PPE. Appropriately equipped first responders should provide assistance to C2 patients where possible and, if necessary, request supplementary assistance from C1 patients if it is safe and practical to do so. Patients who require more extensive assistance or accommodations (C3) will need to be assisted by first responders wearing appropriate protective gear. Unless there is a compelling and urgent reason, deceased individuals should not be moved as part of the IOR as they may constitute forensic evidence and will detract focus from assisting survivors of an incident.

Issues

Although evacuation may appear to be a simple procedure, challenges may arise because of the complexity and number of variables involved. If a safe distance cannot be determined or there are confounding factors, alternative tactics such as "shelter in place" may need to be considered. Moreover, initial decisions may need revision during the incident. Given the wide range of possible contaminants and settings, the available guidance cannot be definitive. Further research is needed to determine the optimum safe distance from the hot zone under different scenarios.

The medical management of C3 patients within the warm zone will be predicated on the availability of PPE, trained first responders and medical transport devices (e.g., stretchers, trolleys, CBRN-hardened vehicles, etc.). The availability of such resources and their estimated time to deployment should already be established (e.g., in local planning and preparedness documents) so that the initial response capacity can be predetermined and interim plans established.

Patients with life-threatening injuries may need to be stabilized before evacuation. However, should the hot zone be clearly life-threatening, evacuation must take precedence over stabilization (29). In such cases, a "snatch rescue" (29) may be required before the specialist resources arrive and the rescuers will need appropriate PPE to avoid becoming patients themselves. It has previously been suggested that a US standard fire fighter ensemble with self-contained breathing apparatus may enable snatch rescues in accordance with the "3-30 rule" (103). The safety of this approach has been questioned, but revised guidance (81) has confirmed the validity of the procedure subject to operational constraints.

Evacuation – Guidance

EVACUATION

Critical Actions

- Take control and maintain effective communication.
- Move patients from the hot zone as soon as possible, preferably to a sheltered (external) area away from strong winds and rain.
- If evacuation is inappropriate, encourage patients in the hot zone to take shelter, close doors and windows, and keep themselves as far removed from the contaminant as possible.

Key Considerations

- The distance between the hot and warm zones needs to be sufficient to ensure the safety of patients but not so far as to adversely impact operational effectiveness or implementation of patient-focused actions.
- The evacuation point should ideally be uphill and upwind from the hot zone.
- Use an effective and accessible communication strategy to emphasize the importance of cooperation to maximize patient safety.

Disrobe

Removal of clothing is an integral part of the decontamination process and should be carried out as soon as practically possible (29, 36, 50, 51, 53, 54). The quantity of contaminant that can be removed by undressing will be proportional to the amount of clothing worn by the patient during the exposure and the exposure trajectory (Figure 9). For example, approximately 50% of a contaminant delivered from an overhead (vertical) spray will deposit on clothed body surfaces. In comparison, up to 70% will deposit on clothing following exposure to an aerosol delivered in a horizontal trajectory. Therefore, timely disrobe will result in the immediate removal of a large proportion of contaminant.

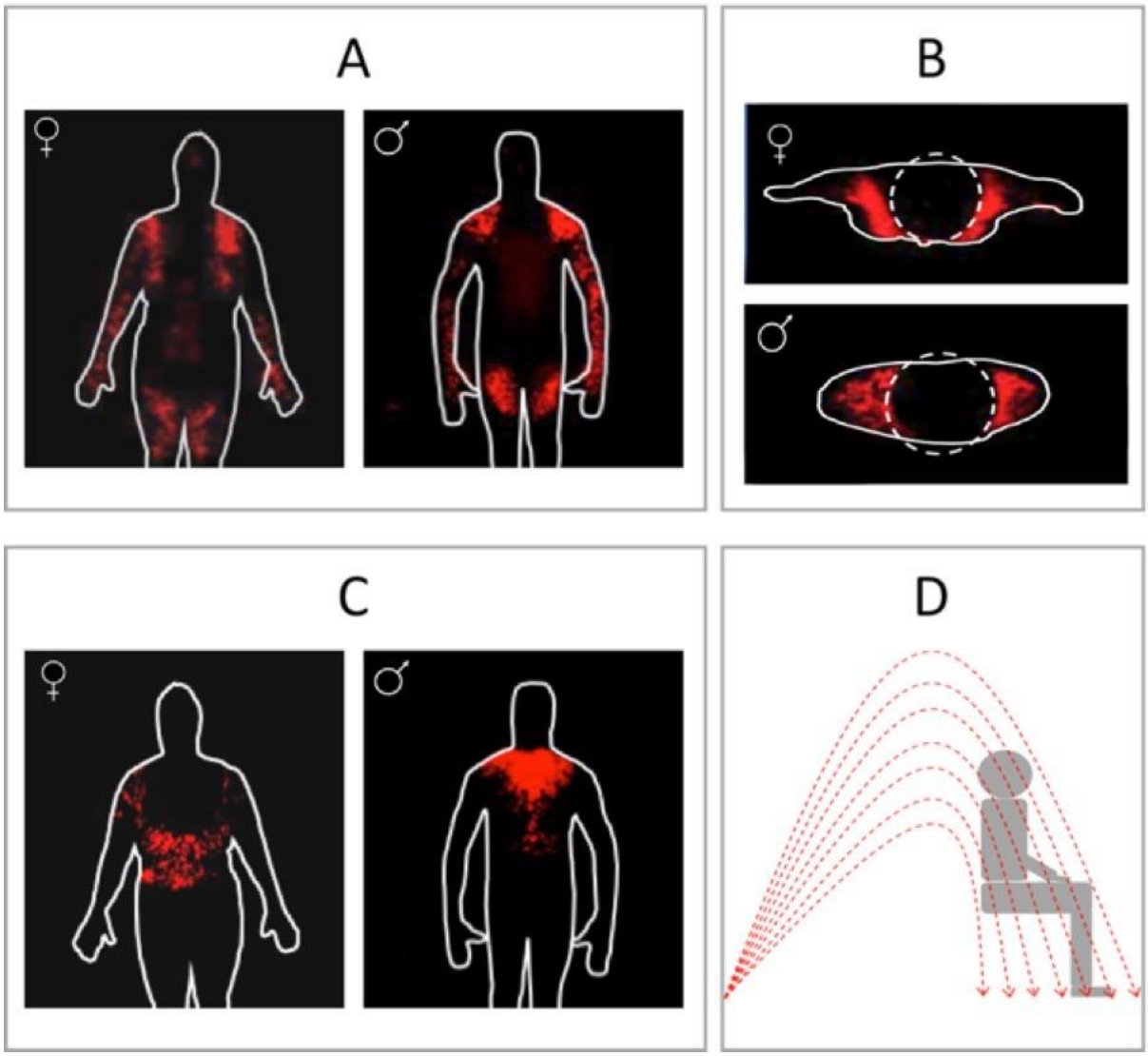

Figure 9: Example of contaminant distribution (red areas) on clothing of a long-haired female and short-haired male volunteer when viewed from the front (A), overhead (B) and back (C). Individuals were seated during exposure; the contaminant was delivered in an aerosol via a parabolic trajectory from behind (D). The absence of contamination on the upper back of the female volunteer was due to the presence of hair.

Communication with patients will be a critical aspect of the disrobe process. Emphasizing the time-critical, clinical benefits of removing contaminated clothing may encourage compliance. It is important to constantly repeat instructions to patients, particularly if there is significant background noise or a large number of patients (30) – see Communication and Patient Management Section (p42).

Efficacy

Removal of clothing is at least an order of magnitude more effective than decontamination for removing liquid chemicals. However, the effect is time-critical (Figure 10) in that the benefit of disrobing decreases rapidly because of penetration of liquid contaminants through the fabric layers (62). Therefore, disrobe should be implemented as soon as practically possible.

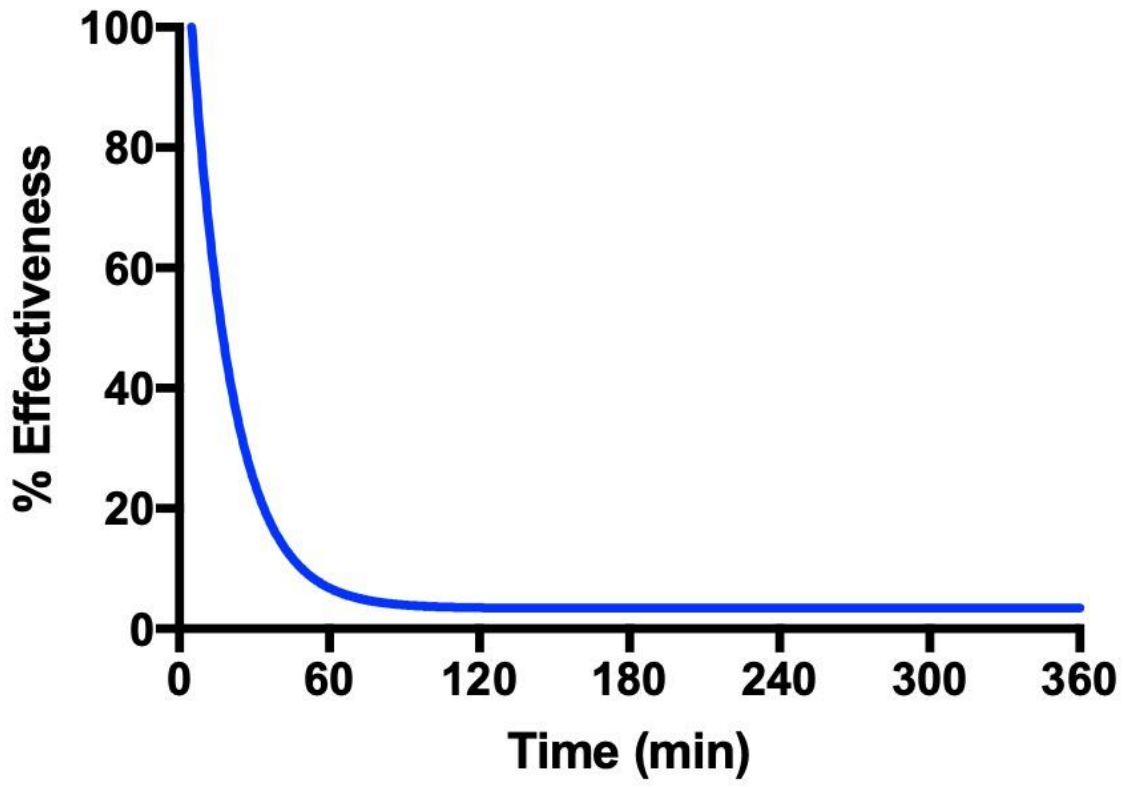

Figure 10: Temporal effects of disrobing, expressed as percentage effectiveness (in terms of reducing underlying skin exposure). Data represents average effect of disrobing against four chemicals; soman (GD), sulfur mustard, VX and methylsalicylate (62).

Operational Benefits of Disrobing

Removal of clothing (and personal belongings) may reasonably be expected to reduce patients' motivation to leave the scene of an incident. Aside from reducing the transfer of hazardous material into the community, the voluntary retention of patients will help limit the number of individuals seeking assistance directly from local medical facilities. Such self-presenting, chemically-contaminated patients will have a detrimental impact on the functional capacity of hospitals (104-107).

Immediate disrobe will also reduce the risk of secondary contamination to first responders arising from direct contact or off-gassing of vapor. Clothing, particularly the heavy or thick materials in over-garments, is known to absorb, retain and subsequently off-gas chemical vapors (62, 108-110). The hazard from off-gassing was highlighted by the sarin attack on the Tokyo subway system in 2005, after which thirteen of fifteen emergency department physicians showed symptoms of sarin exposure that were attributed to off-gassing from contaminated patients and their clothing (111).

Storage and Handling of Clothes and Personal Possessions.

A consequence of implementing disrobe as part of the IOR is that potentially contaminated waste will be generated quickly prior to the arrival of specialist response assets (e.g., chemically-resistant waste containers). Many items, such as jewelry, phones, credit cards, keys, watches and other accoutrements, may have significant commercial, sentimental or practical value. In the case of a terrorist or deliberate release incident, personal items may also constitute forensic evidence and should not be removed from the incident scene. Therefore, all personal items need to be collected and secured. Failure to contain potentially contaminated waste may result in loss of evidence, loss of personal belongings and increased spread of contamination (Figure 11).

Figure 11: Discarded clothes, water bottles and expended dry decontamination material (wound dressings) following a large-scale exercise where appropriate waste receptacles were not provided. Such contaminated items will represent a significant secondary hazard and may result in the theft or loss of forensic evidence or personal valuables, as well as allowing contamination to spread.

Each patient should ideally be provided with a waste receptacle during the disrobe process. If EMS personnel are in attendance, a pragmatic solution will be to provide clinical waste bags (normally available on ambulances). Alternatively, any available type of paper or plastic bag (e.g., trash, grocery or police evidence bag) can be used. However, do not delay patient disrobe if waste receptacles are not available.

Where possible, provide patients with an indelible marker pen to write their name and contact details on their waste container(s). Video recordings of the process (e.g., acquired from "dash cams" or "body cams") can be used to provide additional, retrospective proof of ownership.

When depositing items into the waste receptacle, patients should be instructed to place essential objects (e.g., keys, driving license) or valuables (e.g., credit cards, wallets, money) last and on top of all other items so that they can be readily identified and rapidly processed for return (see "Personal Belongings" section, below).

After removing clothing, patients should be moved away from the disrobe area for emergency decontamination. The remaining items should be isolated within a secure perimeter to prevent loss, tampering, or spread of contamination. When the SOR has been established, officers wearing appropriate PPE should enter the area, place each patient's personal belongings into an evidence bag, record the owner's details (if available) on the evidence bag, and transfer all items to the technical decontamination area. Most plastic or paper bags are not resistant to chemicals; they should be left in place for collection by officers wearing appropriate PPE and subsequently transferred for safe, secure storage in accordance with local guidelines.

Personal Belongings

Where there are sufficient grounds to proceed with disrobe and emergency decontamination, there should be an assumption that personal items are also contaminated; therefore, C1 patients should be instructed to leave all items in the disrobe area.

For C2 patients, certain items (e.g., wheelchairs, medical equipment, mobility aids) can be temporarily retained if (a) loss would immediately lead to C3 patient status and (b) the items are potentially amenable to decontamination. There is no currently no evidence-based guidance to recommend which ancillary items can be successfully decontaminated. As a rough rule of thumb, metallic, glass or other non-porous objects may be suitable for decontamination, although consideration should be given to objects that may be incompatible with exposure to water. It should be noted that rubberized, plastic and leather items may absorb certain chemicals. A more detailed discussion of DME and ancillary items for C2 patients can be found in the Patient Requirements section (p24).

All C3 patients should be disrobed by first responders wearing appropriate PPE. The removal of clothing and personal items should be performed as above, i.e., clothing and non-valuable

items should be placed directly into a waste bag, with valuable/personal items placed on top. If the patient can be identified, the relevant information should be written on the outside of the bag using an indelible marker pen.

The Hazard of Decontamination Without Prior Disrobe

Omission of the disrobe stage has previously been deemed acceptable under certain circumstances (36, 38). This practice must be avoided: it is now widely accepted that clothing should be removed prior to decontamination (16, 17, 21-23) as wet decontamination methods will transfer contamination from the clothing to the underlying skin (2, 3, 7, 8, 10, 12): Figure 12.

Figure 12: Visual demonstration of transfer of a fluorescent contaminant through clothing following wet decontamination. Immediately following contamination (A), the simulant can be visualized on the surface of the clothing. After showering, the contaminant is less intense but remains visible on the clothing surface (B). Removal of the garment demonstrates the degree to which the fluorescent simulant has been transferred by the water onto the underlying skin surface (C).

Procedural Aspects of Disrobe: Standard Response Pathway

There has previously been no consensus on the practical details of disrobing, other than that it should be considered a priority (29, 37, 39, 49, 54). Previous guidance (36) has advised that clothing should be cut off, rather than lifted over the head. If an EMS or Fire Department team are on scene, trauma shears may be available. However, if manual removal of clothing is necessary, patients should be instructed to use their hands to keep the clothing away from their face during removal to prevent potential contamination of the eyes, nose or mouth (36).

Patients on the Standard Response Pathway should adopt the procedure outlined in Table 5 (see also Figures 13-19). This should include all C1 patients, as well as C2 patients who are able to perform disrobe with minimal assistance.

Adverse circumstances (such as very large number of patients) may preclude adherence to the recommended disrobe protocol. In such instances, patients should be instructed to simply "remove your clothes down to your underwear".

The rationale for temporarily retaining footwear (Table 5) is that patients will need to move away from the disrobe area and this may be uncomfortable or dangerous if they are barefooted, particularly if the floor contains debris, has been heated to an unacceptable temperature by direct sunlight or is potentially contaminated. However, overtly contaminated footwear should be discarded during disrobe, as replacement on the feet would be more hazardous.

Table 5: Disrobe procedure for Standard Response Pathway. It is important to constantly communicate the key message that removal of clothing will remove the majority of the contaminant and so represents a simple, but potentially life-saving action. Note that this guidance assumes that patients have been evacuated to an area where floor surfaces are free of contamination and sharp objects and thus safe to walk on barefoot.

Step	Narrative
1a	**Carefully remove headwear** (e.g., hats, caps, scarfs, turbans, hijab, niqab, etc.) by tilting the head back and using a slow front to back lifting motion to avoid transferring contaminant to the face (Figure 13). Note that such items will contain the highest density of contamination following an overhead exposure and their removal is critical to the patient's safety. For headwear that is integral to a partial or full-length garment (e.g., burqa), see step 2a.
1b	Place into an appropriate receptacle, if available. Handle items via inner surfaces where possible to avoid direct contact with contaminant.

Table 5 (continued)

Step	Narrative
2a	**Carefully remove clothing from the upper body**. Where possible, patients wearing full-length garments (e.g., caftan, sari, cassock, overall, dresses, dungarees, etc.) should be encouraged to remove the items via their feet rather than their head, although this may be unavoidable for some items such as cassocks or burqas. • Undo any fasteners (buttons, zippers, Velcro®, etc.) to avoid having to lift garments over the head (Figure 14). • Clothing that does not have fasteners should be cut off by the patient using appropriate implements (e.g., trauma shears, scissors, etc.) if available (Figure 15). • In the absence of cutting implements, instruct patients to pull their arms through to the inside of the garment and to use their arms to prevent direct contact between the item and their face (Figure 16).
2b	Place into an appropriate receptacle, if available. Handle items via inner surfaces where possible to avoid direct contact with contaminant.
3	**Loosen (but do not remove) outer footwear** (shoes, boots, sneakers, sandals, etc.) in preparation for stage 4: Untie or detach all closures (e.g., laces, Velcro®, clutch reels, clasps, etc.). Advise patients to minimize hand contact with footwear. If available, use an appropriate cutting tool for laces and closures. • If loosening is not practically possible (e.g., galoshes, thigh-high boots, etc.), cut items using trauma shears or specialist equivalent (Figure 17). It is not advisable to use scissors, knives or other generic cutting tools for this task because of the inherent risk of laceration. In the absence of an appropriate cutting tool, leave footwear in place and move to step 4.
4	**Move remaining clothing down the body** so it reaches the footwear (Figure 18A&B). Ideally, the inner surface of each garment should be facing upwards to avoid direct contamination if the patient stands on or touches the clothing during step 5a.
5a	**Lift one leg up to dislodge clothing (Figure 18C) and place back down to replace footwear (Figure 18D). Repeat with other leg. Patient should now be unclothed but have retained footwear (Figure 18E).** • Where it has not been possible to loosen the footwear, assistance may be required from first responders wearing appropriate PPE. Alternatively, the patient may be able to remove & replace footwear by handling the items via the inner surfaces of the discarded garments.
5b	Place into an appropriate receptacle, if available. Handle items via inner surfaces where possible to avoid direct contact with contaminant.
6	Patients should **remove all non-essential personal items and valuables** and place these on top of other items in a waste receptacle (if available). If possible, provide patients with an indelible marker pen so that they can write their name and contact details on the outside of the waste receptacle (Figure 19).
7	**Move patients away from the disrobe area**.

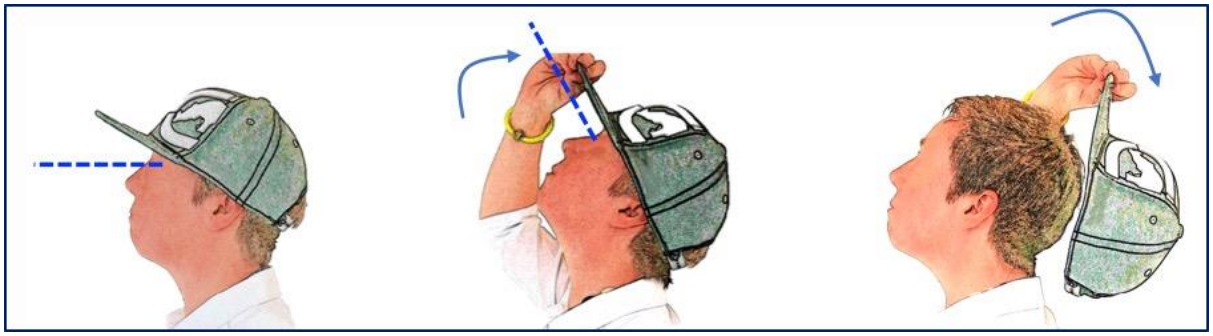

Figure 13: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): <u>Removal of Headwear</u> – tilt head back and remove using a slow front-to-back lifting motion.

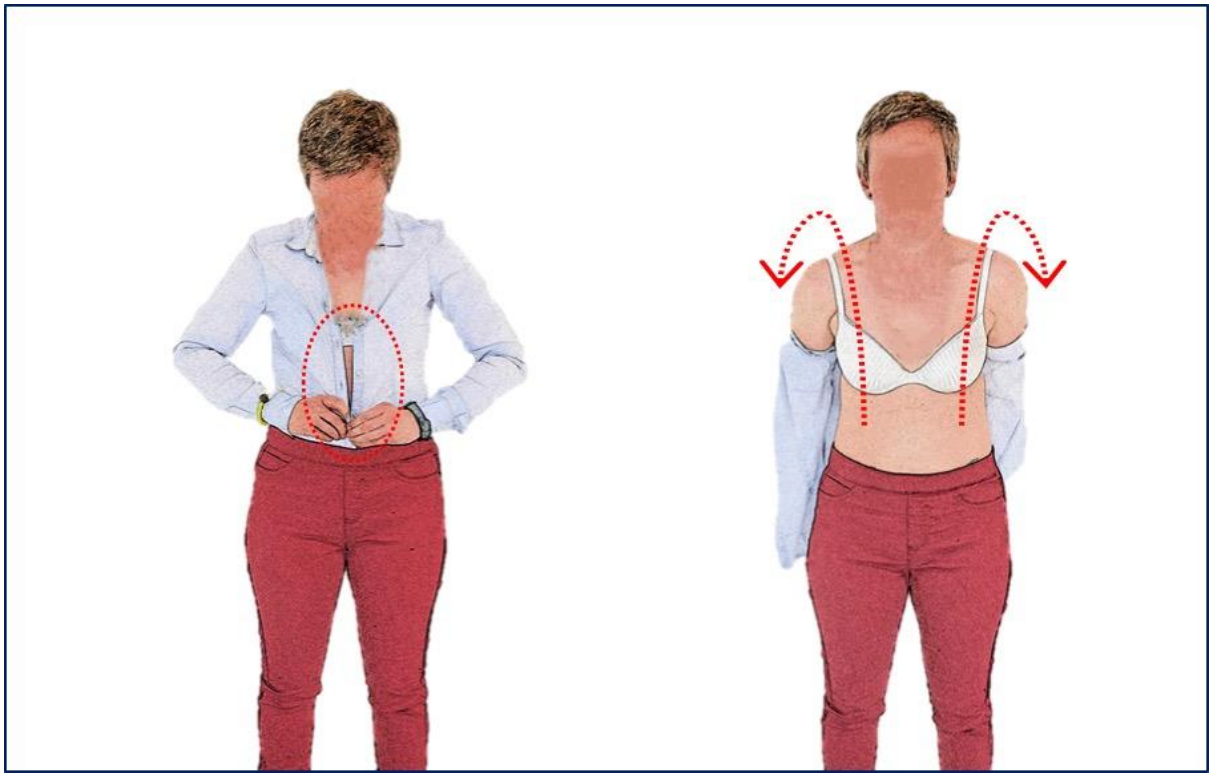

Figure 14: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): <u>Removal of clothes from upper body by undoing fasteners</u>.

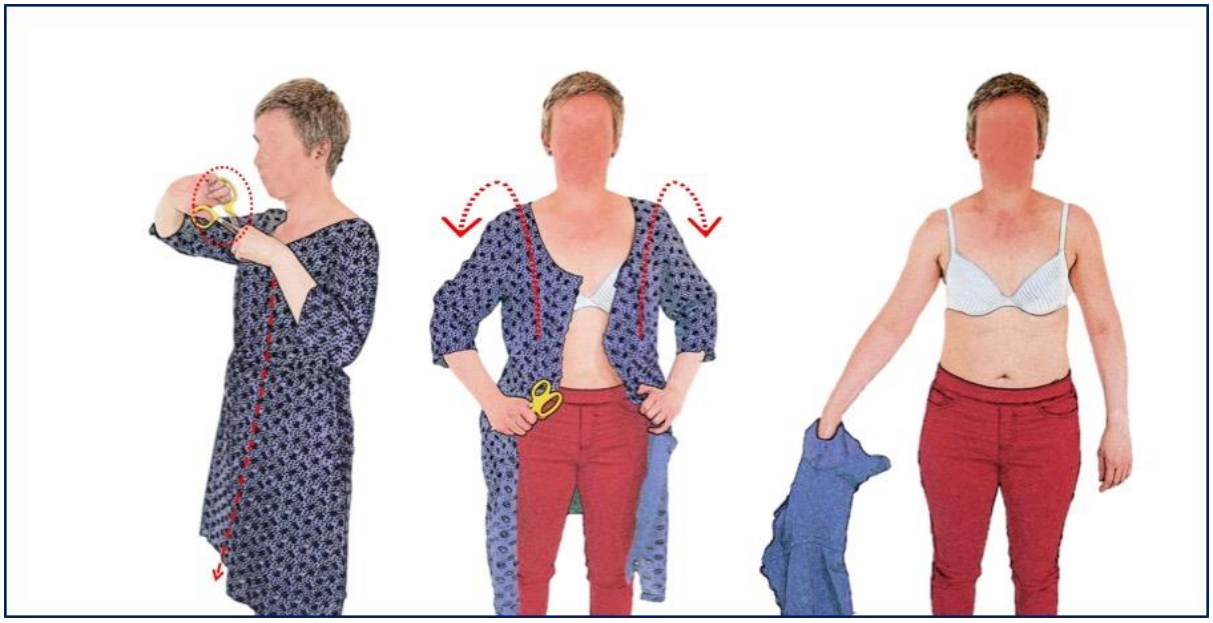

Figure 15: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): Removal of clothes from upper body with no fasteners using a cutting implement.

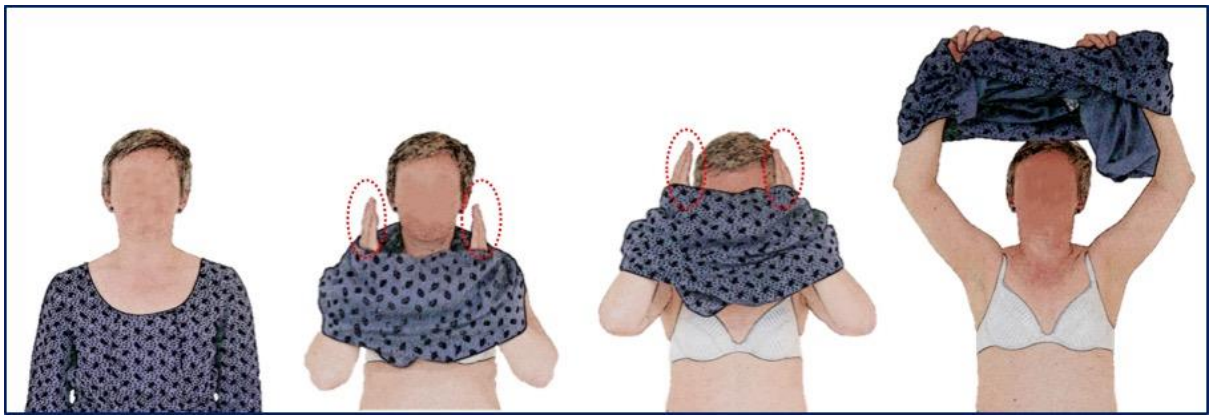

Figure 16: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): Removal of clothes from upper body with no fasteners in the absence of a cutting implement by protecting the head and face using arms inside the garment.

Figure 17: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): Loosening of footwear without readily accessible closures using trauma shears.

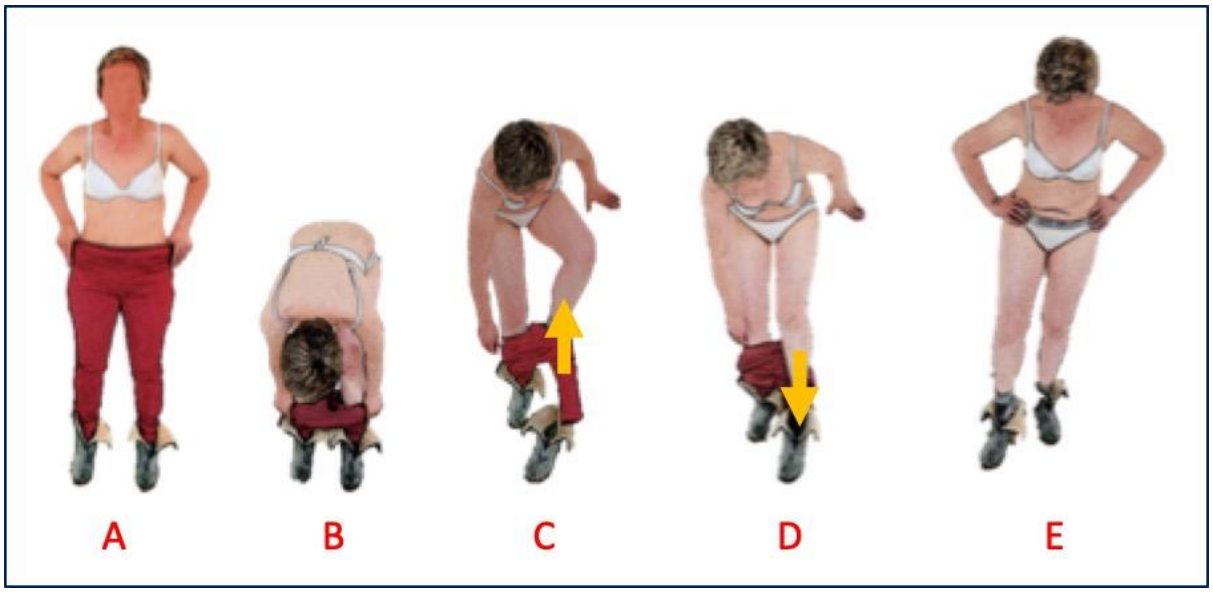

Figure 18: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): Removal of lower clothes (e.g. trousers).

Figure 19: Standard Response Pathway Disrobe Protocol (to be read in conjunction with Table 5): Non-valuable items, clothing and footwear are placed into bag first, with valuable items and personal belongings placed on top. Owner details are written on outside of bag.

Procedural Aspects of Disrobe: Non-Ambulatory Response Pathway

Removal of clothing from C3 patients should be performed as part of the non-ambulatory emergency dry decontamination protocol (see p78; Table 9, Figures 29 and 31). First responders performing this task should wear appropriate PPE and ensure that all requisite equipment and materials are readily available.

Modesty Issues

Several guidance documents emphasize that patients' privacy should be respected during disrobe and decontamination (29, 36, 37, 39, 49, 54), although only two address the issue in relation to public willingness to comply with disrobe and decontamination procedures (29, 37). For example, in a suspected chemical incident at B'nai B'rith Headquarters in Washington DC in 1997, some police officers initially refused to go through the decontamination process because the scene was being broadcast by news cameras on top of a nearby building (112). More recently, a series of linked studies have reported that those who are dissatisfied with the level of privacy during the decontamination process are less likely to comply with decontamination protocols during a real incident (90, 98, 113). Though not directly related to medical outcome, a lack of patient privacy may potentially hinder compliance with disrobe and decontamination procedures and may thus delay the response process.

Historically, guidance has stated that patients may undergo the decontamination process while clothed, if disrobing is not possible for personal or practical reasons (36). However, it should be reiterated that there is now substantial evidence to suggest such practices will result in the transfer of contamination from clothing to the underlying skin and thus place the patients at increased risk of exposure (p55; Figure 12). Consequently, emergency responders should provide patients with as much privacy as possible as long as it does not compromise the effectiveness of the decontamination process. Possible approaches include the provision of disrobe and re-robe suits (if available) or ensuring that decontamination is conducted out of public view. It is important to stress to patients that disrobing is a vital part of the decontamination.

Disrobing: Guidance

DISROBE

Critical Actions

- Remove clothing as soon as practically possible following exposure.
- Do not allow patients to undertake any form of decontamination until disrobe has been adequately achieved.
- Try to preserve patients' privacy & dignity.
- Communication: constantly reiterate the health benefits of disrobing to enhance patient compliance and ensure instructions are understood.

Key Considerations

- Disrobing will immediately reduce exposure and the risk of secondary contamination and may improve the willingness of patients to remain at the scene of the incident.
- A degree of privacy and good communication will enhance patient compliance.
- The effectiveness of disrobing rapidly decreases and so this is a time critical task.
- Focus on compliant patients before dealing with individuals who refuse to cooperate.

Emergency Decontamination

Emergency decontamination is the use of any immediately available material for the rapid removal of contaminants from the hair and skin of potentially exposed patients following disrobe. The process is time critical, as the effectiveness of decontamination may decrease rapidly with time (Figure 20). Therefore, emergency decontamination can be considered a form of "first aid" for treating chemical patients, as it does not require proprietary products and can be self-administered by inexperienced individuals providing they receive appropriate instruction from first responders.

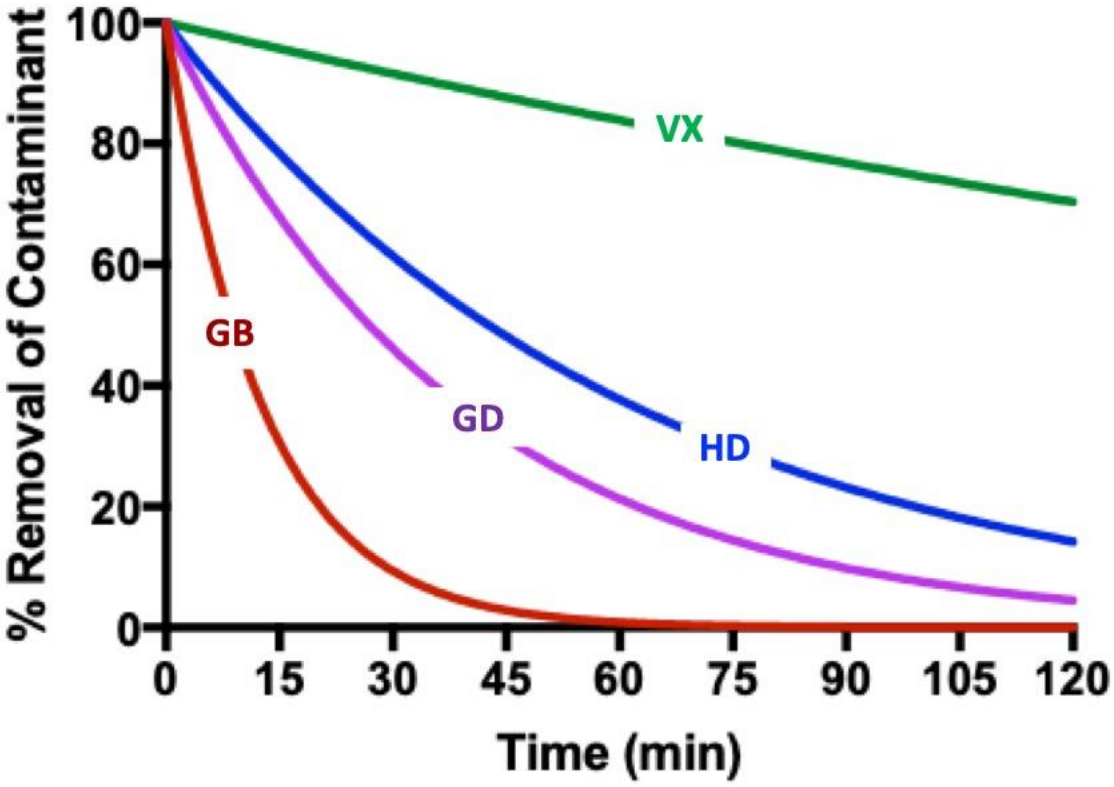

Figure 20: Effect of time on the effectiveness of skin decontamination, expressed as the maximum achievable percentage removal of the chemical warfare agents GB (sarin), GD (soman), HD (sulfur mustard) and VX, as predicted by the ASPIRE algorithm. Note that this does not equate to clinical efficacy (which will be primarily dependent on the percutaneous toxicity of the contaminant and the extent of contamination). Aside from the clinical benefit to each patient, rapid decontamination will also reduce the risk to first responders by decreasing off-gassing (inhalation hazard) and limiting the potential for direct transfer of contamination (dermal contact hazard).

Dry Versus Wet Emergency Decontamination

The default option for emergency decontamination should be "dry" (Figure 21). That is, the application of dry, absorbent materials to exposed areas of skin and hair. This is particularly the case for liquid contaminants such as chemical warfare agents, as the application of water to the skin surface may substantially enhance dermal absorption via a phenomenon known as the "rinse-in" or "wash-in" effect (114-117). In contrast, emergency wet decontamination should only be used where the contaminant is overtly caustic or particulate (e.g., powder) in nature (Figure 21).

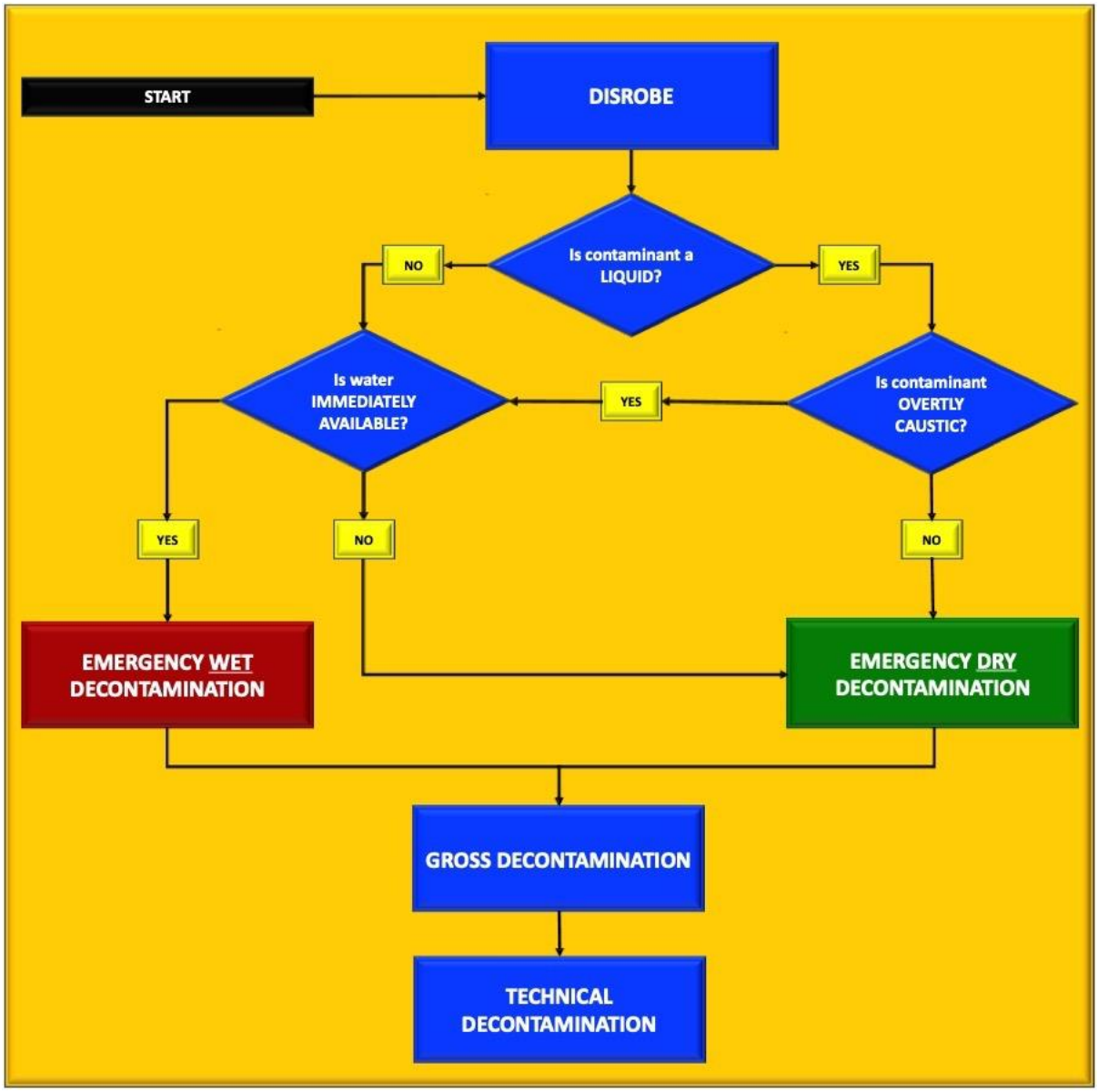

Figure 21: Flow chart to identify the most appropriate form of emergency decontamination. The basic rule is that unless the contaminant is particulate and/or caustic, dry decontamination should be the default option.

Who Should Administer Emergency Decontamination?

All first responders should be aware that evacuation, disrobe and emergency decontamination are simple but potentially life-saving methods that must be performed at the earliest stages of a chemical incident. However, no first responder should put their own life at risk and direct contact between potentially contaminated patients and first responders who are not wearing appropriate PPE must be absolutely avoided at all times. If it is apparent that the environment is immediately dangerous to life or health, first responders should retreat to a safe distance. However, that does not necessarily preclude shouting advice to patients to evacuate away from potential sources of contamination.

The concept of emergency dry decontamination for C1 and, where appropriate, C2 patients is for self-administration; thus, it may be possible to instruct patients to implement these procedures, if they can be safely provided with decontamination materials and are within hearing distance of first responders. Evacuation, disrobe and emergency decontamination of C3 patients requires close contact and thus donning of appropriate PPE by first responders. In certain circumstances, this may be achievable using more readily available equipment (e.g., firefighter self-contained breathing apparatus in standard turn-out gear), although this is a contentious issue (81, 103, 118).

Figure 22: Emergency medical service personnel providing instruction for emergency dry decontamination from a safe distance during an exercise.

Emergency (Self-Care) Dry Decontamination

The introduction of dry decontamination to the incident response process is to establish a rapid means of treating exposed patients prior to the availability of a functional LPS or Technical Decontamination Units. Dry decontamination is fundamental to the concept of the IOR and should be instigated immediately following disrobe if appropriate. The relative merits and disadvantages of dry emergency decontamination are summarized in Table 6 and are discussed in more detail below (p69).

Table 6: Dry decontamination: pros and cons.

Advantages	• Does not require specialist products or an immediate source of water. • Can be performed with any dry, absorbent material. • Produces solid waste, which is easier to contain than effluent from wet decontamination. • Is at least as effective as wet forms of decontamination. • Mitigates the risk of enhancing dermal absorption (via the "rinse-in" effect). • Improves the outcome of subsequent wet decontamination procedures, i.e., has a synergistic effect when performed as part of the "Triple Protocol".
Disadvantages	• Is ineffective against particulate contamination (e.g., powders). • Can be ineffective if patients are not properly supervised. • Less effective than wet decontamination for removing contaminants from hair and underlying scalp skin. • Likely to be viewed with distrust by patients unless delivered as part of an effective communication strategy by first responders.

Emergency decontamination should be performed as part of a series of patient-focused actions that form the IOR. The mnemonic that links these key stages of evacuation, disrobe and decontamination is "EMERGENCY" (Table 7).

Table 7: The "EMERGENCY" mnemonic for the evacuation, disrobe and dry decontamination components of the Initial Operational Response (119).

E	**Evacuate**: Patients should be instructed to leave the contaminated area if they have not already done so (p46).
M	**Move** the patients as a group to a safe distance, away from any potential source of contaminant (p48). Ideally this should be uphill and upwind and preferably in a sheltered (external) area away from strong winds and rain.
E	**Engage** with patients to explain what is happening and how they can help themselves by following instructions and advice (p48). Some patients may not wish to cooperate for cultural, religious or other reasons: focus initial attention on compliant individuals. Maintain an awareness of patient requirements.
R	**Remove** as much clothing as possible (p51). It is important to communicate the benefits of rapid disrobe to the patients in order to gain their cooperation (p62). The more clothes that are removed the better, but be mindful of modesty concerns. Where possible, do not remove clothing over the head. If available, trauma scissors can be used to cut away clothing (p55).
G	**Give** any available absorbent material to the patients. Ideal materials include "Wypall™" (absorbent paper tissue), wound dressings, incontinence pads, cotton wool, toilet paper, diapers and paper towels. Do not get close to patients when handing out the decontamination material.
E	**Establish** dry decontamination on all C1 and C2 patients as soon as possible. Using a blot and rub motion, start with the head (hair), face, then the hands, then any other exposed skin areas. If availability of material permits, instruct patients to use clean swatches of absorbent material for each body area. Above all, ensure that patients do not re-use material after decontaminating their hair. Encourage patients to repeat the entire process several times, paying particular attention to the hair, face and hands.
N	**Note** the development of any signs and symptoms. Begin triage to identify priority patients.
C	**Communicate** constantly with patients to encourage cooperation and reassurance that disrobe and decontamination will remove the vast proportion of any contamination. Confirm to the patients that advanced medical assistance is on its way.
Y	**Yards not inches**: Maintain a safe distance from patients at all times, but close enough so that they can hear instructions.

Disadvantages

Dry decontamination is contraindicated for use with particulate (powder) contamination as it is ineffective at removing particles from the skin surface (21, 120).

Recent studies have demonstrated that first responders need to effectively supervise and communicate instructions to ensure that all patients perform the dry decontamination protocol in an adequate manner: when performed in accordance with instructions, dry decontamination can attain up to 99% removal of liquid contaminants from skin surfaces, but lack of compliance may reduce efficacy (25, 28, 30, 31).

An important issue that needs to be addressed during an incident is the potential reluctance of patients to fully engage with the dry decontamination process due to the misconception that it is not as effective as wet decontamination (31, 78). The fact that dry decontamination is at least as effective as wet decontamination on skin surfaces needs to be constantly communicated by first responders. It may be worth noting that dry decontamination has been the predominant method deployed by military forces over the last century (121, 122) and that studies have consistently demonstrated the superiority of dry over wet forms of decontamination (123-125). Moreover, there is evidence to suggest that the standard "rinse-wipe-rinse" method of wet decontamination is less effective than dry decontamination for removing liquid skin contamination (120).

Advantages

The overriding advantage of emergency dry decontamination is the fact that it does not require specialist products (such as proprietary brands of decontaminant) or an immediate source of water and so can be rapidly instigated during the inherent delay associated with deployment of an LPS corridor. This delay could be significant: at the very minimum, an LPS corridor will require 12 minutes to establish and, unless pre-deployed, there will be an additional delay associated with transport of assets to the incident scene. It would not be unrealistic to anticipate a *minimum* delay of at least 17 minutes before a fully functional LPS corridor becomes available (p91). During this time, toxicologically-significant quantities of chemicals may otherwise be absorbed through the skin, so dry decontamination provides a simple means of addressing this critical capability gap. The effect of such a delay on decontamination efficiency is clearly demonstrated in Figure 20.

The application of water to the skin surface (when performed as part of an emergency wet decontamination process) will result in contaminated waste that will be difficult to control and could potentially spread contamination over a larger area of the body. In contrast, dry decontamination does not spread contamination over the skin surface (28) and the materials used by the patients can be placed into a temporary receptacle (e.g., clinical waste bag or

standard garbage bag) for initial containment prior to subsequent disposal as part of the specialist operational response.

There is a growing body of evidence to demonstrate that dry decontamination is more effective than wet forms of decontamination for liquid contaminants (120, 123-125); this may be attributable, at least in part, to elimination of the "rinse-in" effect that has been observed during wet decontamination (114-117).

Dry decontamination has been shown to improve the outcome of wet decontamination procedures by acting in synergy with wet decontamination when performed as part of the "Triple Protocol" incident response (28, 30). It may also significantly reduce the subsequent contamination of towels during the process of active drying (p98) and the accumulation of contaminant vapors within technical decontamination structures (28).

It has previously been suggested that dry decontamination is preferable to wet decontamination during cold weather (29, 36, 37), as it may reduce the risk of hypothermia.

Dry Decontamination Materials

The selection of a dry decontaminant should primarily be based on the availability of suitable materials. It is important to note that "wet wipes", as their name implies, are not a dry decontaminant material and their use may enhance the dermal absorption of oil-soluble (lipophilic) chemicals (125).

A range of readily available absorbent products are demonstrably effective for emergency dry decontamination (51, 120): these include paper towels, wound dressings and incontinence pads (Figure 22), most of which are usually available on a standard EMS ambulance. Suitable domestic items include kitchen or toilet tissue, diapers and cotton wool. As a rough rule of thumb, any material that is likely to be absorptive should provide at least some degree of effectiveness as a decontaminant, although the most practical materials (in terms of quantity available) are rolls of absorbent tissue.

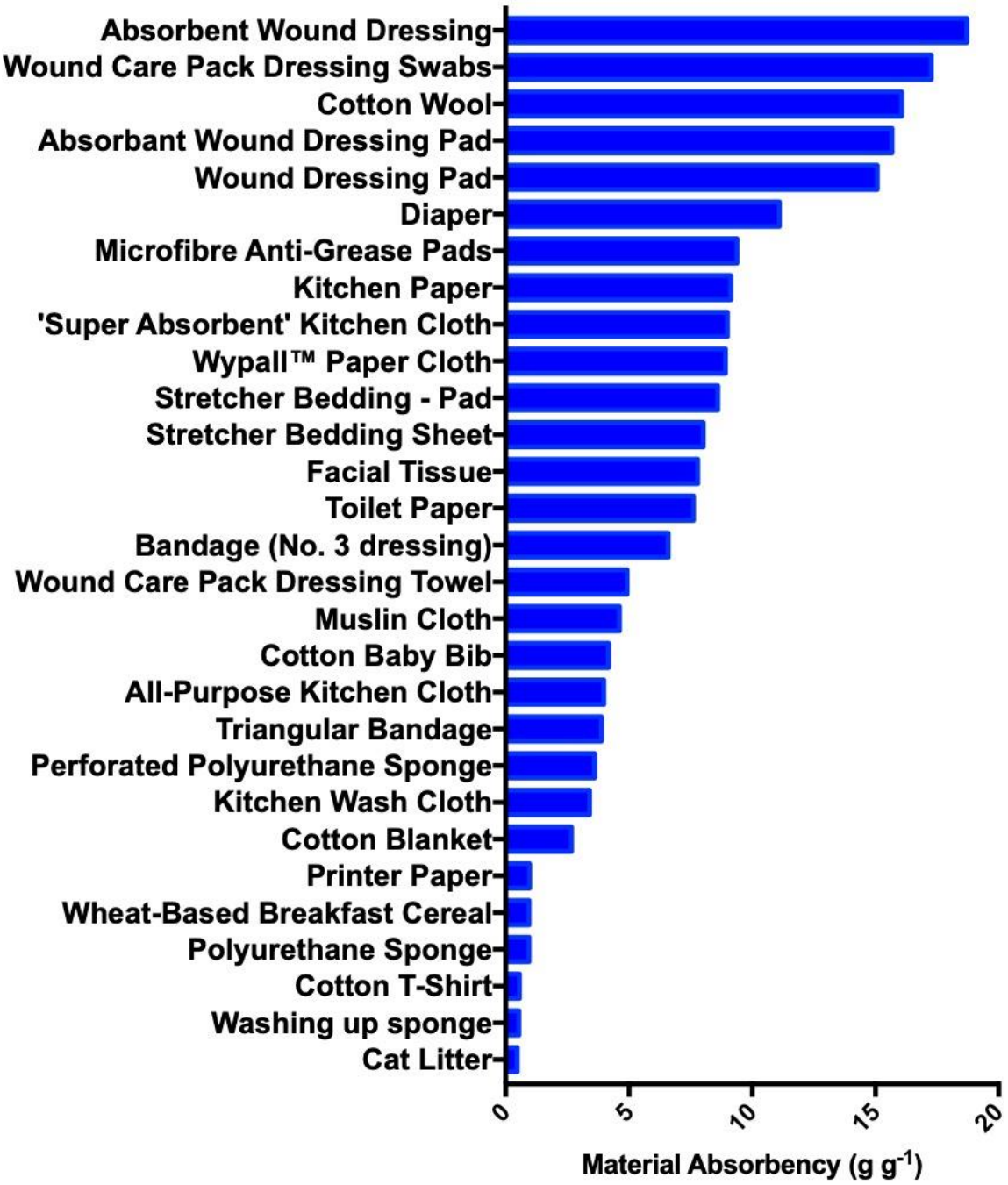

Figure 22: Absorbency of a selection of materials found within domestic or medical environments, expressed as weight of oil or water absorbed per gram of material. For example, an absorbency value of 10 would indicate that one gram of material can absorb 10 g of oil or water. Data from Kassouf et. al. (120).

Dry Decontamination Protocols

Several guidance documents provide recommendations for performing dry decontamination based on blotting, wiping or combined blotting and rubbing of the skin (29, 36, 54). The most recent evidence supports the combined blot-and-rub technique (78). Dry decontamination should start with the hair (or top of head), followed by face, hands and then any other areas that were not initially clothed (and were thus potentially exposed). When performed correctly, dry decontamination is at least comparable in effectiveness to wet forms of decontamination (25, 28, 31).

All C1 patients should use the Standard Response Pathway protocol for emergency dry decontamination. If sufficient decontamination material is available, patients should be instructed to repeat the process until gross decontamination facilities become available. Where possible, C2 patients should be encouraged to use the same protocol, taking into account the possible need for additional assistance. All C3 patients will require the Non-ambulatory Response Pathway protocol for dry decontamination.

Emergency Dry Decontamination Protocol: Standard Response Pathway

Dry decontamination should be performed in an area sheltered from wind and rain, away from the disrobe area. The time taken to perform evacuation and disrobe should be used to identify and acquire any available source(s) of decontamination material. Additional material should be provided by supporting officers throughout the dry decontamination process to ensure an adequate supply is maintained, particularly during larger-scale incidents.

The basic dry decontamination process involves a logical head-to-toe approach, with 10 seconds of blotting per main body area (e.g., head, face or hand) followed by 10 seconds of rubbing the same body area (10:10 technique): Table 8. Ideally, fresh decontamination material should be used for different body areas. The focus should be on areas of the body that were not originally clothed during exposure. Under extreme circumstances, dry decontamination of the entire body can be performed in 60 seconds without a change of material between body areas and still effect significant removal of contamination from hair and exposed skin surfaces (28).

Factors for first responders to consider include their ability to effectively communicate with patients over background noise while maintaining a safe distance. Counting aloud the 2 × 10 second durations for each body area may help synchronize patient activity and so avoid the need to provide different instructions to individuals within the same group.

Table 8: Emergency Dry Decontamination Protocol for Standard Response Pathway.	
Step	**Narrative**
1	**Identify and acquire dry decontamination material.** • EMS may have immediate access to wound dressings, incontinence pads and rolls of absorbent tissue paper and clinical waste bags. • In the absence of EMS supplies, seek any available absorbent material, such as toilet tissue, diapers or cotton wool.
2	**Check that all patients have undergone disrobe** (Figure 23A&B).
3	**Communication**: inform patients that… • They are about to undertake dry decontamination. • This is a potentially lifesaving measure to remove dangerous chemicals from their hair and skin. • It is important that they can hear and follow instructions. • Further decontamination may be necessary.
4	**Focusing on the head (hair) first:** • Provide decontamination material and encourage patients to tilt head backwards (Figure 23C). • Instruct patients to use a blotting motion on the top and sides of the head/hair for at least 10 seconds (Figure 24A) and then use a rubbing motion for at least 10 seconds (Figure 24B).
5	**Disposal:** Place the used decontamination material into any available receptacle (e.g., waste bag) **taking care not to touch the "dirty side"** (contaminated surface of the decontamination material): Figure 24C.
6	**Next, decontaminate the face:** • Using a fresh (unused) piece of decontamination material, blot around the face for at least 10 seconds (Figure 25A) and then use a rubbing motion for a further 10 seconds (Figure 25): "10:10 approach".
7	**Disposal:** Place the used decontamination material into any available receptacle (e.g., waste bag) **taking care not to touch the "dirty side"** (contaminated surface): Figure 25D.
8	**Then decontaminate the hands:** • Use a fresh (unused) piece of decontamination material. • Blot the front and back surfaces of one hand for 10 seconds followed by a rubbing motion for a further 10 seconds (Figure 26A&B). Pay particular attention to areas between the fingers. • Ensuring that the same "dirty" side is used, blot the front and back surfaces of the other hand for 10 seconds followed by a rubbing motion for a further 10 seconds, again paying particular attention to areas between the fingers.

Table 8 (continued)

Step	Narrative
9	**Disposal:** Place the used decontamination material into any available receptacle (e.g., waste bag) **taking care not to touch the "dirty side"** (contaminated surface of the decontamination material): Figure 26C.
10	**Using the same blot-then-rub technique, decontaminate any other skin areas that were not originally clothed.** • Use a fresh (unused) piece of decontamination material for each individual area being decontaminated and use the 10:10 approach (10 seconds blotting, 10 seconds rubbing). • Remind patients that open footwear (e.g., sandals, flip-flops, etc.) means skin on the feet should be decontaminated: patients will need to step out of their footwear to perform this task – they should not put on their footwear again and may require assistance. • The rear of the neck and back of the legs are also frequently missed areas. • Dispose of each piece of decontamination material as per step 9.
11	**Repeat process from step 4** until gross or technical decontamination facilities are available or there is no further supply of decontamination material available.

A simplified version of emergency dry decontamination is illustrated in Figure 27.

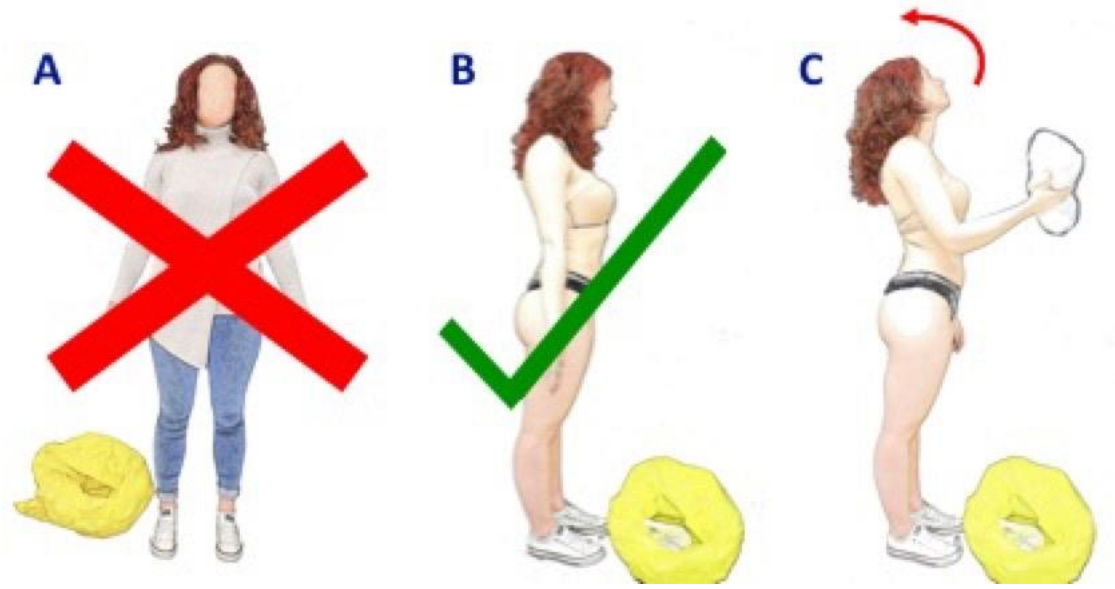

Figure 23: Standard Response Pathway Dry Decontamination Protocol: ensure that patients have undertaken disrobe [A, B]. Start dry decontamination with the hair, tilting the head back to reduce contamination of the face. If sufficient decontamination material is available, place used material into an appropriate waste receptacle [C].

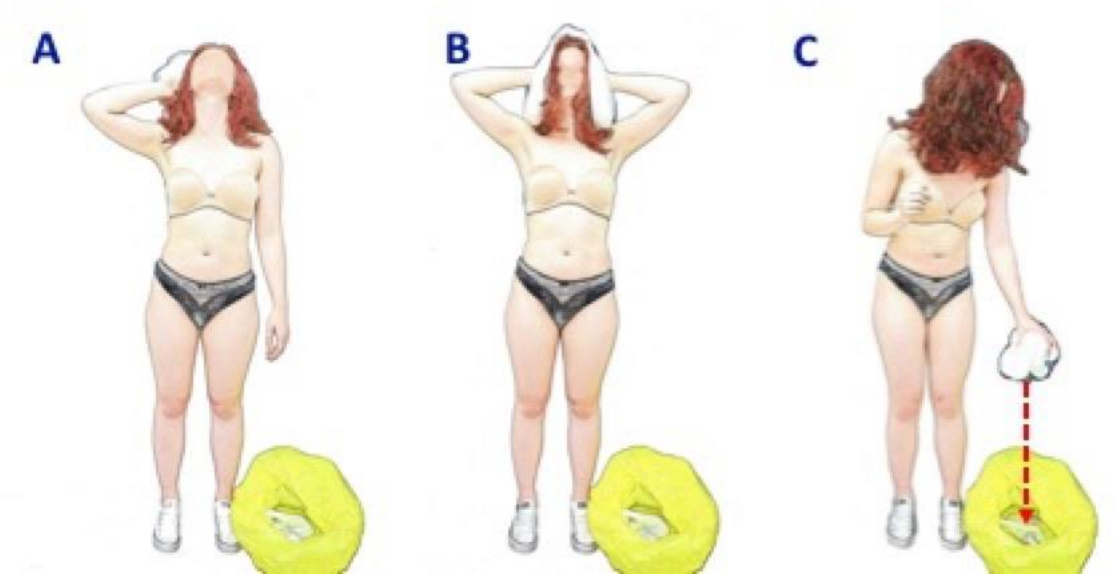

Figure 24: Standard Response Pathway Dry Decontamination Protocol: Blot then rub the hair/head, using the 10:10 approach [A, B], disposing of used absorbent material if sufficient material is available [C].

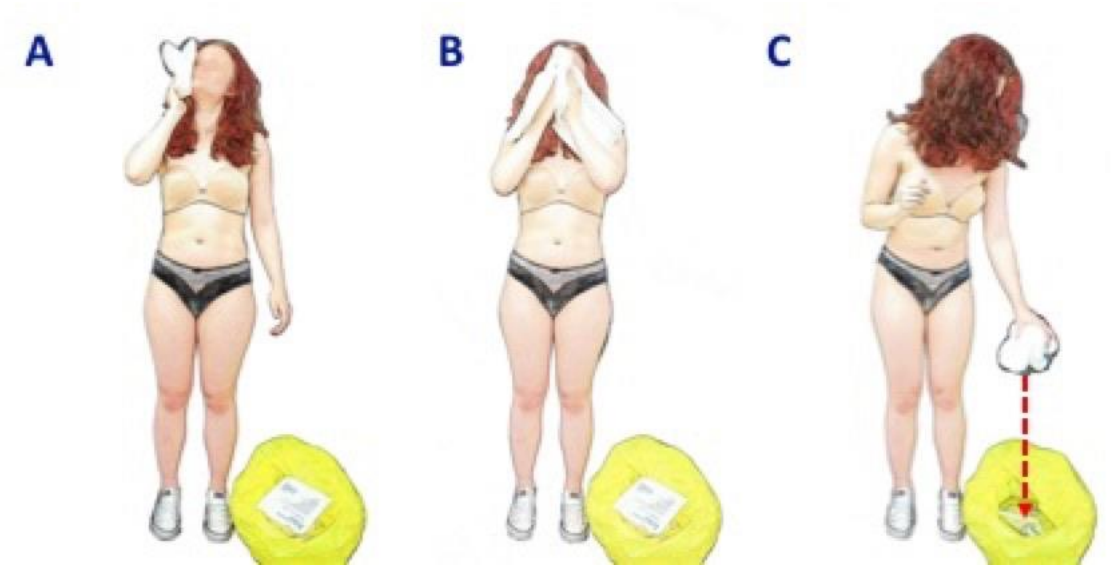

Figure 25: Standard Response Pathway Dry Decontamination Protocol: decontaminate the face next, using the same 10:10 approach [A, B], ideally using a fresh piece of decontamination material, which should be placed into an appropriate waste receptacle [C].

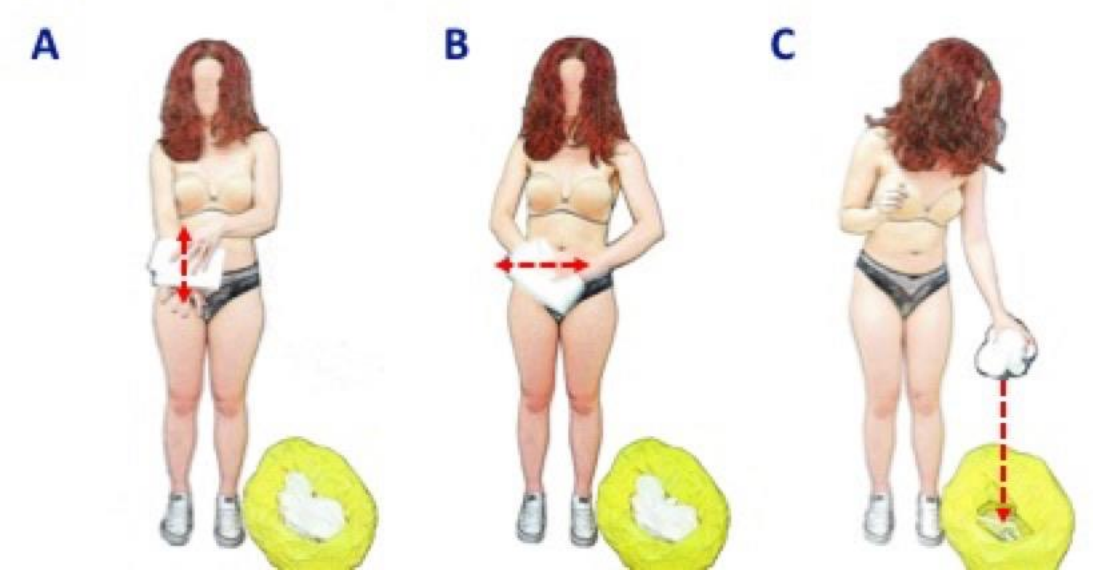

Figure 26: Standard Response Pathway Dry Decontamination Protocol: Use the 10:10 approach to clean both surfaces of the hands [A, B], ideally with fresh decontamination material, which should then be placed into a waste receptacle [C]. Using clean decontamination material (if available), proceed to decontaminate any other areas of potentially exposed skin.

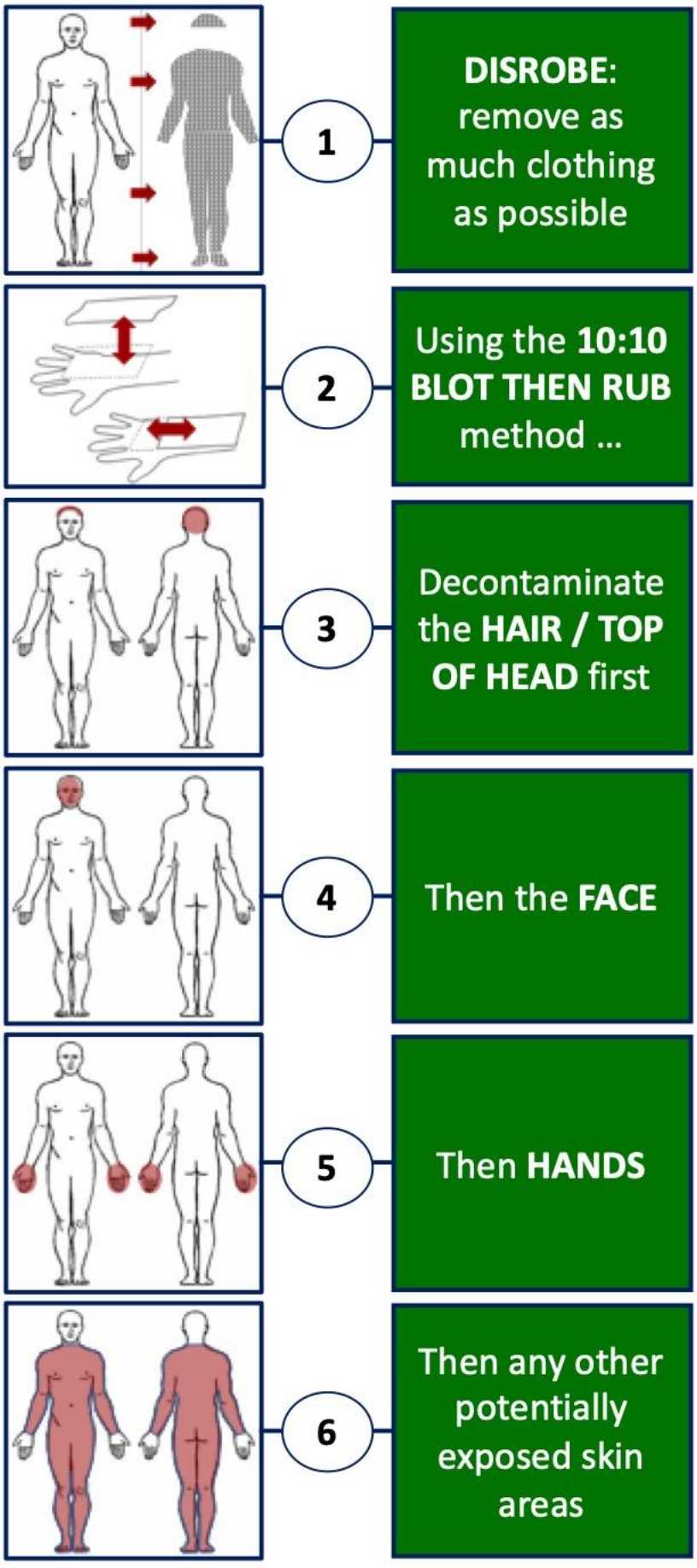

Figure 27: Pictogram demonstrating the blot and rub method for performing dry decontamination. Following disrobe [1], use the 10:10 technique (blotting for 10 seconds followed by rubbing for 10 seconds) to apply the decontamination material [2]. Ideally, clean decontamination material should be used for each step (subject to availability). Clean the top and sides of the head first [3], with head tilted back. Next, decontaminate the face [4]. The hands should be cleaned next [5], followed by any other skin areas that may not have been initially protected by clothing [6]. Repeat steps 3–6 as necessary. Use clean decontamination material for each step (if available in sufficient quantity). Used decontamination material should be placed by the casualties into a suitable waste receptacle (e.g. clinical waste bag, bin liner, etc.) immediately after use.

The basic process requires three responding officers wearing appropriate PPE, two long spine boards ("backboards" or "spinal boards"), a supply of dry decontamination material, a garbage receptacle (e.g., clinical waste bag) and sanitary/disinfecting solution (Figure 28). A detailed description of the process is provided in Table 9. Under experimental conditions, the non-ambulatory disrobe and dry decontamination process can be performed in three minutes (52). However, it should be noted that this protocol has not been evaluated under more realistic conditions, such as an exercise, so the durations stated in Table 9 are for guidance only.

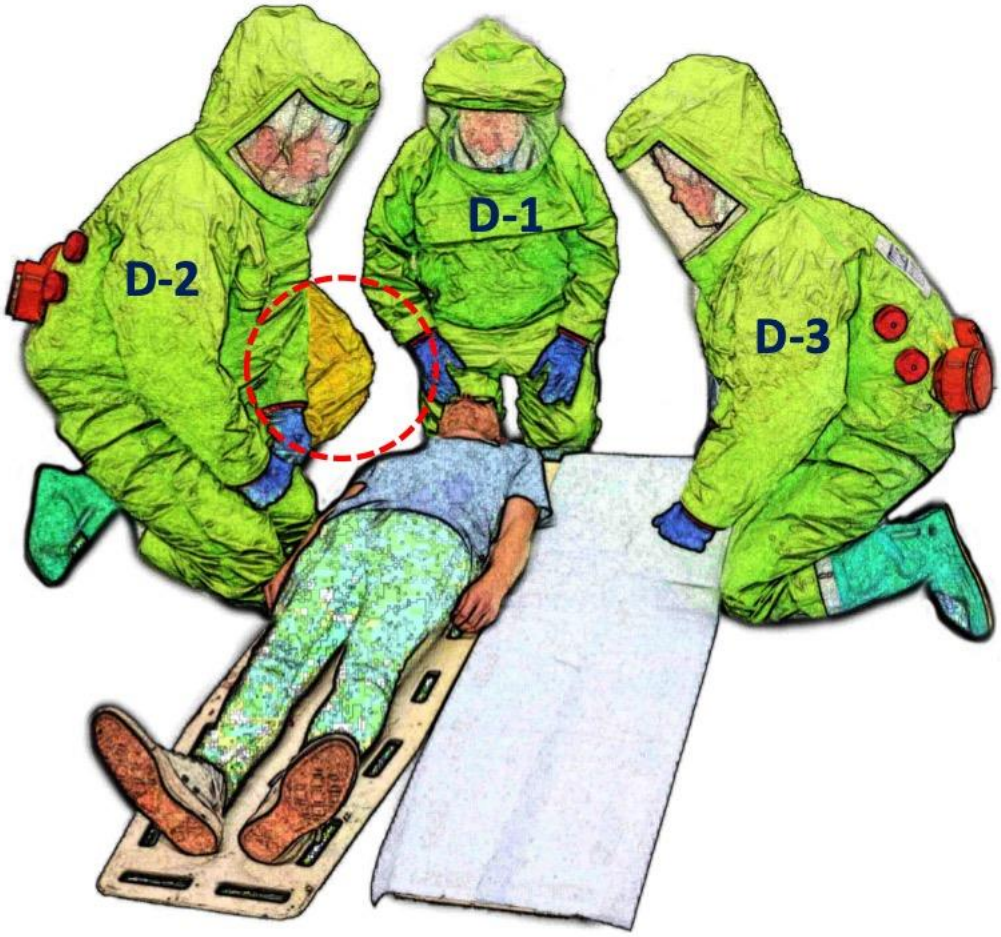

Figure 28: Basic setup for non-ambulatory dry decontamination indicating positions of the three responding officers (D-1 through D-3). The patient is transferred to the decontamination area on a spinal board (or similar, non-absorbent stretcher). A second, clean spinal board is prepped with absorbent material (e.g., incontinence pads, paper tissue). Two waste receptacles are required, one (ringed on diagram) for contaminated decontaminant material and one for personal items and valuables which should be placed on top of discarded clothing.

Table 9: Disrobe and Emergency Dry Decontamination Procedure for Non-Ambulatory Response Pathway (52). This process can be performed in three minutes.	
Step	**Narrative**

1	**Preparation:** in addition to standard emergency medical supplies, non-ambulatory disrobe will require:
	• A minimum of three response officers wearing appropriate PPE:
	  ○ The officer at the apex of the spine board (D-1) supports the patient's head and neck at all times, monitors airways/breathing and performs hair/scalp decontamination (Figure 29).
	  ○ The responding officers either side of the patient (D-2 and D-3) perform disrobe and all other decontamination functions (Figure 29).
	• Two spine boards (or equivalent constructed from non-porous material).
	• Trauma shears.
	• Supply of dry decontamination material.
	• At least two garbage receptacles (e.g., clinical waste bag) per patient.
	• Sanitary/disinfectant solution.

2	**Manage immediately life-threatening injuries** (e.g., severe hemorrhage; Figure 30) if safe to do so, but do not unnecessarily delay disrobe and decontamination.
3	**Disrobe:** Remove clothing using an appropriate cutting tool (e.g., trauma shears). D-1: support head and neck at all times. Instigate hair/scalp decontamination using rubbing action (one hand at a time). D-2 & D-3: cut and peel back clothing (e.g., Figure 31), minimizing contact with the underlying skin to avoid cross contamination.

4	**Dry Decontamination – Front of Body:**
	• D-1: support head and neck at all times, monitor patient's airways/breathing. Continue hair/scalp decontamination.
	• D-2 & D-3: Instigate dry decontamination.
	  ○ **Start with exposed skin surfaces on front of body.** i.e. **Face, hands and any other areas that were not covered by clothing** (Figure 32A).
	  ○ Use the "10:10" blot and rub technique (p72).
	  ○ **Frequently replace decontaminant with fresh material**, placing used decontaminant into the *second* garbage receptacle, i.e., not the same container as the discarded clothing.
	  ○ **Repeat dry decontamination on all other accessible skin surfaces** that were originally clothed (Figure 32B).

5	**Prepare to Roll into Recovery Position:** • D-1: **support head and neck at all times**, monitor patient's airways/breathing. Temporarily suspend hair/scalp decontamination. • D-2: place patient's knee and arm into correct position (Figure 33A). • D-3: place patient's contralateral arm into correct position and press knees against clean board to prevent slippage during the roll procedure (Figure 33A).

Table 9 (continued)

Step	Narrative
6	**Roll Procedure:** • D-1: **support head and neck at all times**, monitor patient's airways/breathing and when patient has been prepared, provide verbal command for roll procedure*. E.g. "on three …" D-2 & D-3: on command from D-1, provide sufficient force **to roll patient into recovery position** on the clean spinal board (Figure 33B).
7	**Dry Decontamination – Back of body:** • D-1: support head and neck at all times, monitor patient's airways/breathing. Continue hair/scalp decontamination. Replace decontamination material if visibly contaminated. • D-2: o Remove clothing from dirty (first) spinal board (Figure 34A), fold (so that external surfaces face inwards) and **place clothing into *first* garbage receptacle** (Figure 34B)**, placing any personal or valuable items on top.** o **Clean original spinal board** using sanitary/disinfectant solution to remove any blood, body fluids or tissue (Figure 34C). o Assist with dry decontamination procedure. • D-3: o **Start dry decontamination of potentially exposed skin surfaces on back of body.** i.e. **Neck, hands and any other accessible skin areas** that were not originally covered by clothing (Figure 34D). o Use the "10:10" blot and rub technique (p72). o **Frequently replace decontaminant with fresh material**, placing used decontaminant into the *second* garbage receptacle (Figure 34B), i.e. not the same container as the discarded clothing. o **Repeat dry decontamination on all other accessible skin surfaces** that were originally clothed
8	**Reverse Roll Procedure:** • D-1: **support head and neck at all times**, monitor patient's airways/breathing and when patient has been prepared, provide verbal command for roll procedure*. E.g. "on three …" D-2 & D-3: on command from D-1, provide sufficient force **to roll patient back** onto the original **(**clean) spinal board. Patient may be transferred to technical decontamination. Seal the second garbage receptacle (containing decontamination waste using medical adhesive tape or any other means. Write details of patient (if known) on bag.

*It is recommended that D-1 provide the verbal command to coordinate rolling the patient as this officer has a superior view of the whole body.

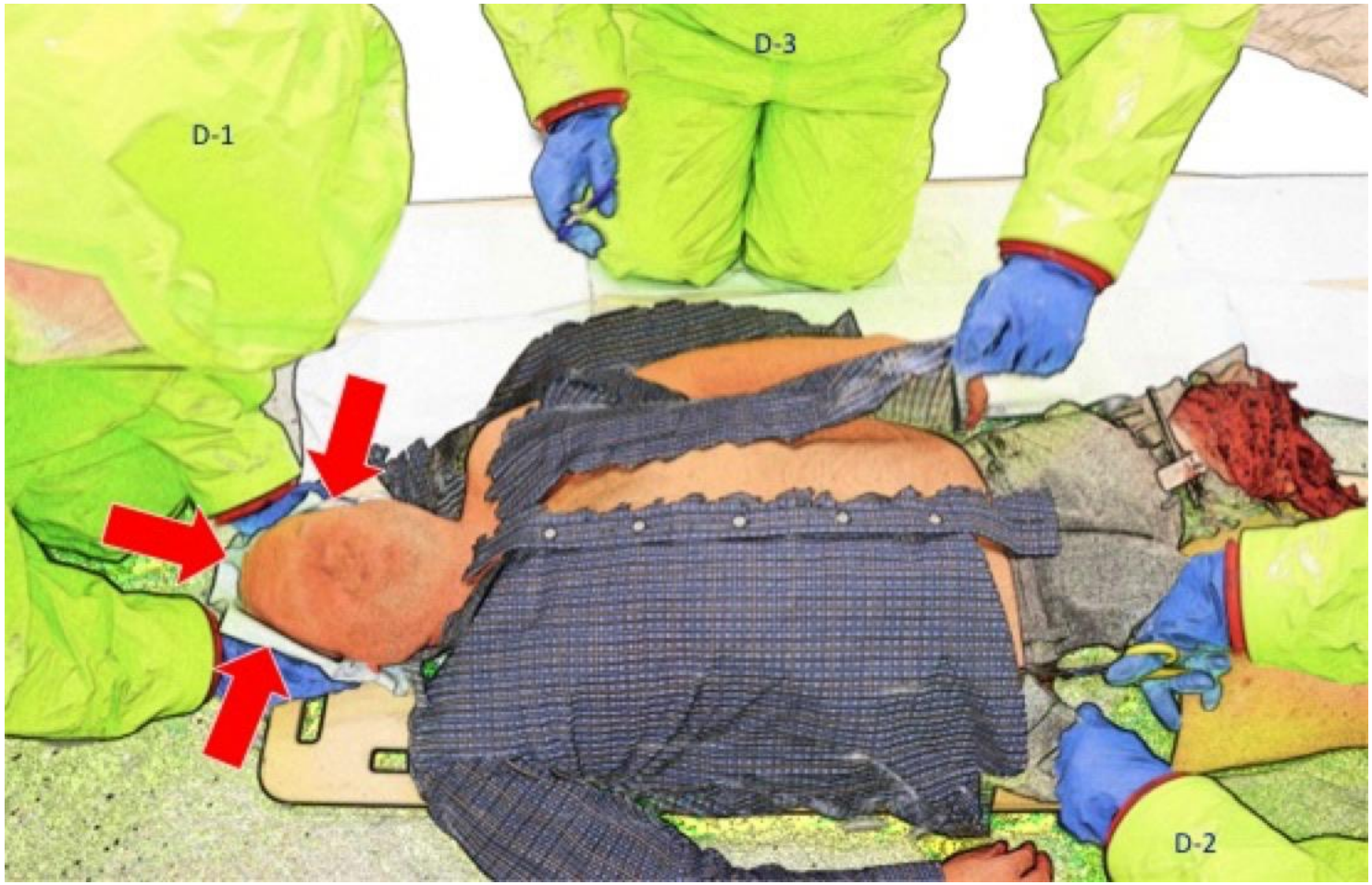

Figure 29: Response officer at the apical position of spine board (D-1) constantly supports the patient's head/neck and ensures a patent airway. The patient is separated from the first responder's gloves by the decontamination material (indicated by red arrows). Decontamination is achieved through a rubbing action performed using one hand at a time (to allow head to remain supported). Note that response officers D-2 and D-3 are disrobing the upper and lower body regions, respectively.

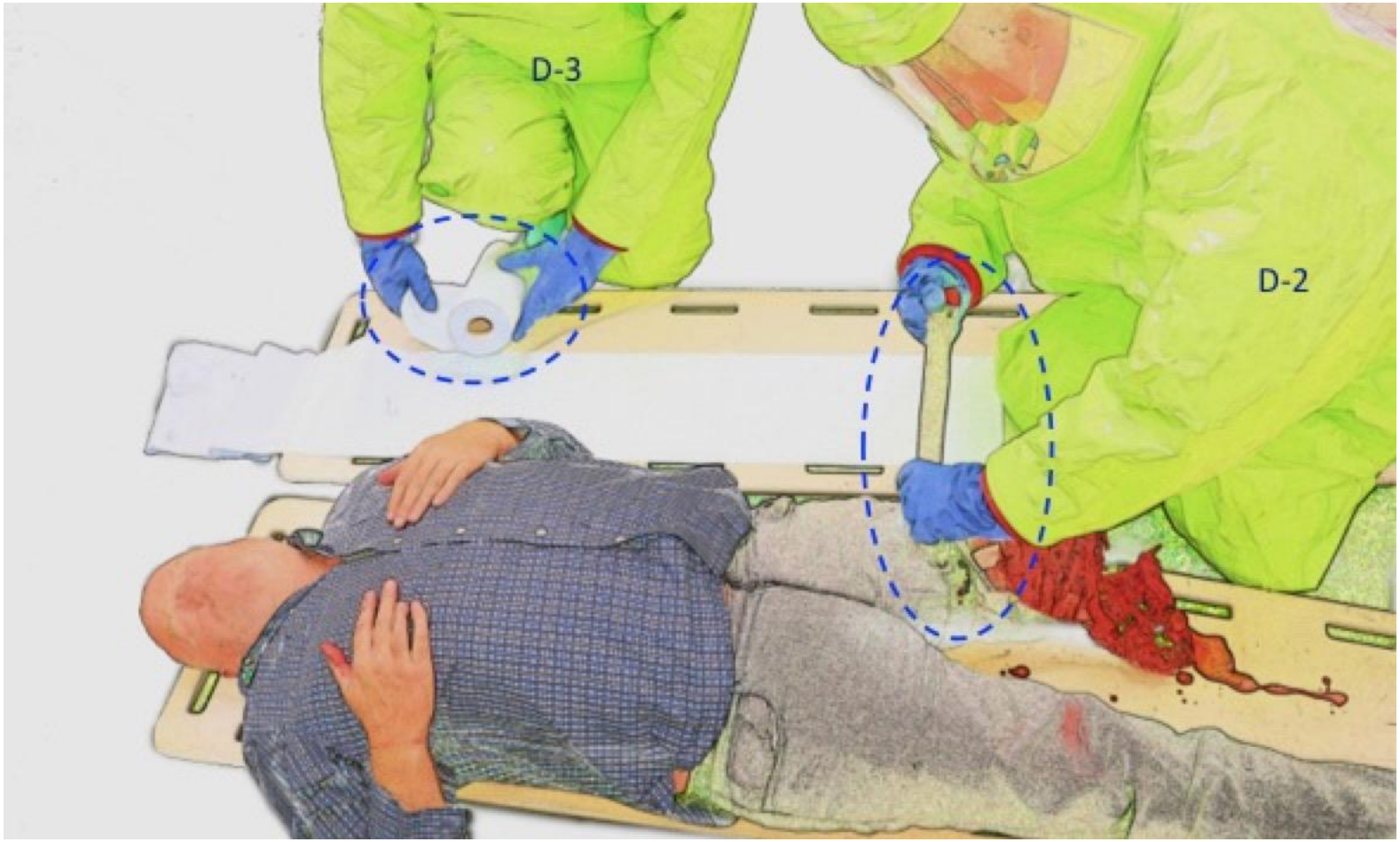

Figure 30: Application of a tourniquet by a responding officer (D-2) to patient's limb to prevent lethal hemorrhage, with tandem preparation of the adjacent "clean" board (in this example, by layering with absorbent tissue) by response officer D-3. [D-1 officer omitted for clarity].

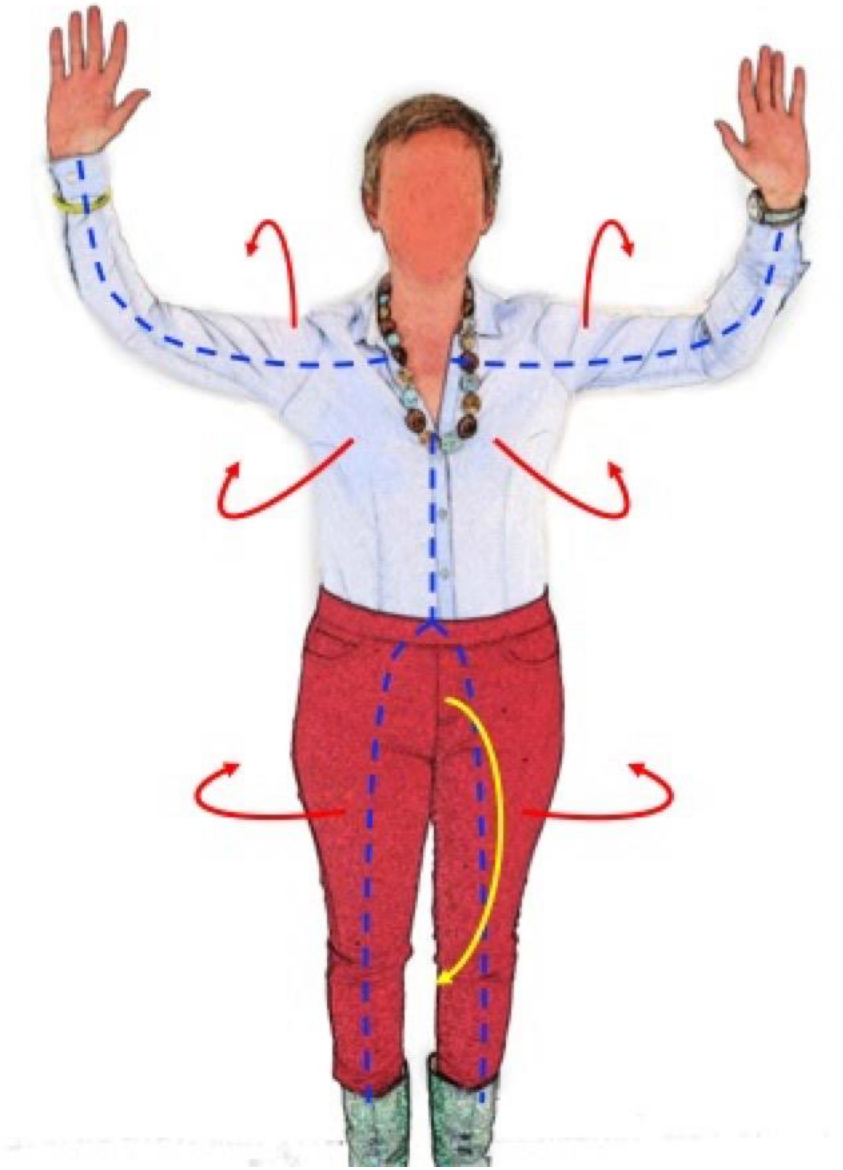

Figure 31: Example of cut lines (dotted lines) and direction in which to peel cut clothing away from body (arrows). Care should be taken to ensure that the outer surfaces of clothing do not make skin contact to avoid transfer of contaminant. Note that all jewelry must also be removed. Place clothing in a bag labelled with known details of patient, placing valuables and personal items on top of clothing.

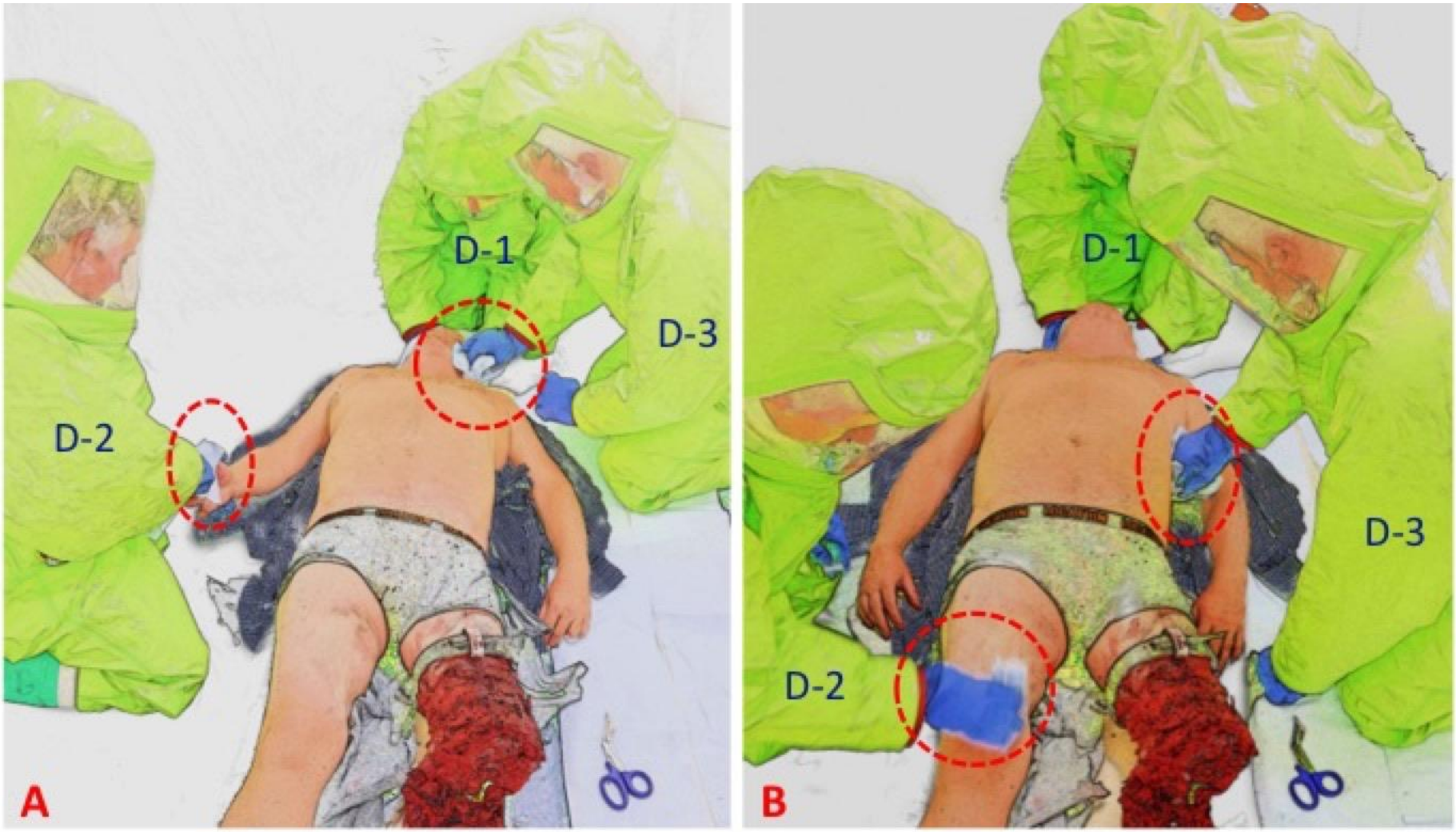

Figure 32: Non-ambulatory Emergency Dry Decontamination Protocol – Front of Body. Focus initial attention on areas of the body that were not originally clothed during exposure – in this example, the face, neck and hands (A). Apply decontamination material using the 10:10 technique (10 seconds blotting and 10 seconds rubbing) and then move onto all other areas of skin that were originally clothed (B).

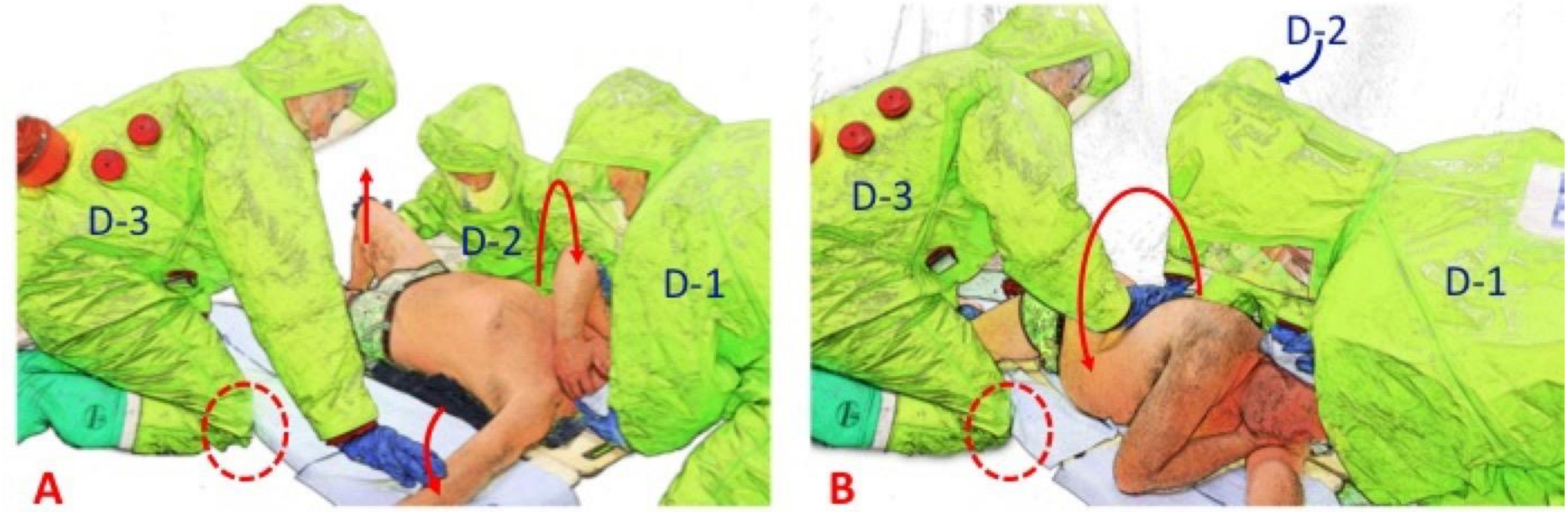

Figure 33: Transfer of Non-ambulatory Patient to Recovery Position. In this example, response officer D-2 raises the patient's right knee and moves the right arm across the upper chest so that the right hand supports the chin (left image; A). The patient's left arm is rotated perpendicular to the body by response officer D-3 (left image; A). The head and neck remain supported at all times by D-3, who provides verbal coordination for rolling the body into the recovery position on the adjacent spinal board. In practice, the clean spinal board (which the patient is rolled onto) will tend to slide away from the dirty board during the roll process. To prevent this, D-3 should kneel against the clean board to apply a counteracting force (B).

Figure 34: Non-ambulatory Emergency Dry Decontamination Protocol – Back of Body. D-2 officer to remove clothes from first spine board (A) and carefully place into an appropriate garbage receptacle, in this example, a clinical waste bag (B). Place any valuables or personal items onto the top of the discarded clothing and write the details (if known. Use sanitary/disinfectant solution to remove any body fluids or tissue from the first spinal board (C), dry and place fresh decontamination material on the surface of the spinal board (D). During this time, D-3 officer should reinstate dry decontamination (using blot then rub technique), initially focusing on areas that were not protected by clothing during exposure.

Emergency Wet Decontamination

Wet emergency decontamination should only be performed when dry methods are contraindicated. That is, for caustic or corrosive chemicals (indicated by burning or painful skin) or non-liquid (powder or particulate) chemical contaminants. There is currently no quantitative evidence available for recommending a specific emergency wet decontamination protocol.

Wet Decontamination Materials

In principal, any immediately available source of water can be used, such as bottled water, soft drinks and fruit juices or lukewarm/cold (not hot!) beverages, such as tea and coffee. Any form of wet decontamination should incorporate active drying (p98). Aside from assisting removal of contaminants, dry absorbent material can be used to prevent excess water spreading contamination to other body areas.

Wound Decontamination

Skin and hair decontamination are the primary focus when responding to incidents involving exposure of patients to toxic materials. However, certain types of incident may result in the presentation of patients with traumatic wounds (penetrating injuries, cuts, lacerations, etc.) contaminated with toxic materials. Such injuries may significantly enhance the local or systemic absorption of chemicals and, consequently, result in a more rapid onset and increased severity of adverse health effects (126-128).

One previously suggested but flawed approach for mitigating the effects of contaminated intradermal or penetrating wounds is through irrigation with dilute hypochlorite solution (129). It is important to note that this approach is not supported by experimental studies and is not recommended by current National Planning Guidance because the active ingredients may elicit acute, local toxicity and there would be insufficient contact time to adequately neutralise chemical contaminants (29). Moreover, it has been demonstrated that the use of dilute bleach solutions may result in more extensive skin lesions in wounds contaminated with a vesicant agent (130).

More recent studies have identified powder-based, absorptive hemostatic products as effective skin and wound decontamination products for chemical warfare agents (126-128, 131-133), although any absorbent material may potentially have some beneficial effect. Thus, in the absence of powder-based (absorptive) hemostatic products, sterile gauze pads or wound dressings may provide a practical alternative. Given the enhanced toxicokinetics associated with absorption of chemicals through damaged skin, wound decontamination should be prioritized over hair and skin decontamination.

EMERGENCY DECONTAMINATION

Critical Actions

- Emergency decontamination is time critical – do not delay.
- Ensure patients have adequately disrobed.
- Prioritize open wounds for decontamination, ideally using absorbent wound dressings.
  - Decide which form of decontamination (dry or wet) is appropriate:
    - DRY decontamination is the default option using any readily available material
    - Use wet decontamination for powders or overtly caustic chemicals.
- Constantly provide instructions and communicate with patients to emphasize clinical benefits of emergency decontamination.

Basic Protocol

- Instruct C1 & C2 patients to decontaminate from top to bottom, concentrating on areas most likely to be contaminated (e.g. hair/head, face, neck, hands) and to repeat until additional resources (e.g. LPS) become available.
- C3 patients should be treated by trained first responders using the non-ambulatory dry decontamination protocol.
- Provide constant supervision and communication to ensure patient compliance.
- Focus on compliant patients before dealing with individuals who refuse to cooperate.

Gross Decontamination

In the US, gross decontamination for mass patients is synonymous with LPS decontamination (38). The LPS is a simple and robust decontamination technique whereby two fire engines are parked in parallel to produce a decontamination corridor. A high-volume mist (or "fog") of water is introduced to the corridor via the engines' side pumps, supplemented with an overhead spray. Traditionally, the overhead spray is delivered via a fogging or misting nozzle attached to a ladder that spans the corridor, hence the term "ladder pipe" system (Figure 35). Alternatively, aerial platforms can also be used to provide the overhead source of water (Figure 2). The implementation of LPS decontamination represents the start of the SOR phase.

Figure 35: Ladder Pipe System (LPS) Decontamination. Water is fed into the decontamination corridor via three fogging or misting nozzles (circled): one from each engine's side pump and one attached to an overhead ladder. Picture taken during "Exercise PROTEUS", performed at the Center for Domestic Preparedness, Anniston, Alabama, in May 2015 (12). Note that in this example there are two exercise artefacts: the patient is wearing exercise-specific clothing (shorts and cotton t-shirt) and is being supported by a first responder. During a live incident response, disrobe should be performed prior to decontamination and patients would be expected to undertake LPS with no (C1) or minimal (C2) assistance (Figure 3).

As with all forms of decontamination, the LPS process is time critical (see Figure 20). Unless one is pre-deployed, there will inevitably be a delay between exposure of patients and availability of a functional LPS corridor. A well-trained Fire Department team can configure an LPS corridor in approximately 12 minutes (30). The turnout time and response time may add a further 5 minutes (134) and so there will be a delay of *at least* 17 minutes before a functional LPS corridor is available. Thus, emergency decontamination should be instigated during this delay period in order to maximize the clinical benefit for patients. To reiterate, emergency dry decontamination and LPS decontamination act synergistically and should be performed as part of the "Triple Protocol".

Gross Decontamination Protocol for Standard Response Pathway

Previous work (performed under the BARDA-sponsored "Advanced Studies of Mass Patient Decontamination" (135)) evaluated the LPS in a series of linked studies that focused on key parameters, such as timing, hydrodynamics, effect of disrobing and the use of detergents (1-3, 6-11). The main findings are summarized in Table 10.

Table 10: Summary of main research findings of the BARDA-sponsored "Advanced Studies of Mass Patient Decontamination" Project, circa 2012–2015 (1-3, 6-11).

LPS Parameter	Synopsis
Effect of Delay	A time-dependent decrease in the effectiveness of LPS was frequently observed. Correspondingly, emergency and LPS decontamination should be instigated as soon as practically possible, otherwise decontamination may be ineffective at minimizing adverse health effects of exposure.
Hydrodynamics & Water Temperature	The standard flow rates achieved by LPS are effective and consistent with a short (e.g., <30 second) shower duration.
Clothing	The presence of clothing during LPS decontamination reduces the effectiveness of decontamination and can cause transfer of contaminants from clothing to underlying skin. This supports the recommendation to disrobe prior to showering.
Detergents	The addition of detergent to LPS shower water does not significantly improve the effectiveness of decontamination, supporting the recommendation that gross decontamination should not be delayed for the introduction of detergent into shower water.

More recent research (conducted under the BARDA-sponsored project "GO-AHEAD" (136) has confirmed the detrimental effects of a delay and has provided evidence that LPS decontamination is not affected by different exposure geometries or contamination densities. That is, the effectiveness of LPS is consistent over a range of exposure scenarios. More importantly, the recent work has extended the evaluation of LPS to include hair decontamination (Table 11).

Table 11: Summary of main research findings pertaining to LPS decontamination from the BARDA-sponsored "GO-AHEAD" Project, circa 2015–2018 (14, 17-19, 21, 22, 26, 28).

LPS Parameter	Synopsis
Dose and Droplet Geometries	The effectiveness of the LPS is not affected by the number of liquid droplets applied at a constant contamination density (1 mg cm^{-2}) and is independent of contamination density (1–100 mg cm^{-2}) when the contaminant is applied as a single liquid droplet.
Duration	A 15-second shower is comparable in effectiveness to longer durations.
Hair Decontamination	LPS is reasonably effective for removing contaminants from the surface of hair. However, the outcome is significantly improved when performed in combination with an (initial) emergency dry decontamination step. Nevertheless, a substantial reservoir of lipophilic (oily) contaminants will remain within the hair and is not amenable to any practical form of decontamination.

An advantage of LPS as a gross decontamination technique is that it is well structured and controlled and can be deployed while response assets such as technical decontamination units are awaited (51). Disadvantages include the necessity of using cold water (taken directly from fire hydrants) and the difficulty of protecting patients' modesty (112). The risk of hypothermia from showering with cold water is considerable, especially if the ambient air temperature is below 64˚F (~18˚C) (29). Failure to protect patients' privacy may result in delays to the decontamination process if patients are reluctant to comply with recommended procedures (98). Disrobe suits have been suggested as a means to protect patients' privacy when undergoing decontamination (54), although this is obviously dependent on immediate availability. An alternative that addresses the issues of privacy and hypothermia risk is the Emergency Decontamination Corridor System, or EDCS (36). While being slower to set up than the LPS, this has the advantages of including salvage covers for privacy and portable heaters for warmth.

There is a growing body of evidence to suggest that a 15–30 second duration is sufficient for LPS decontamination (2, 3, 7, 8, 10, 14, 17, 18). One reason for this is that the flow rate of water during LPS is in excess of that required to achieve adequate decontamination (Figure 36).

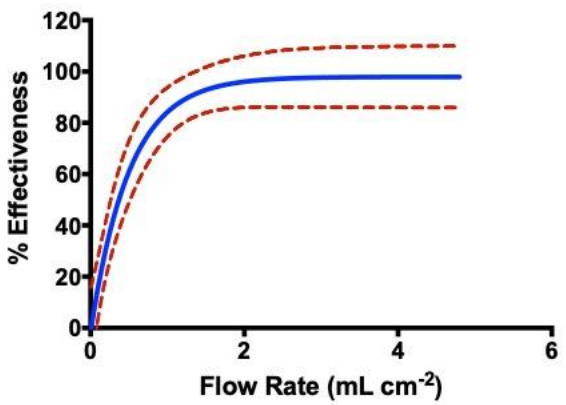

Figure 36: Effect of water flow rate on average skin decontamination effectiveness for lipophilic chemicals (137). Dotted red lines indicate 95% confidence interval. Note that flow rates for LPS have been measured in the range ~10–40 mL cm^{-2} min^{-1} (138). No relationship between water flow rate and decontamination effectiveness was demonstrated for a water-soluble contaminant (139).

No difference in the effectiveness of LPS decontamination has been observed between cold (50ºF; 10ºC) and warm (95ºF; 35ºC) water (2, 3, 7, 10); thus, whilst showering in warm water would be less hazardous and more comfortable for patients, cold water is acceptable from an operational perspective.

A particular problem that has received insufficient attention is the difficulty of decontaminating hair. Though LPS decontamination has been a recommended approach, its efficacy and operational impact had not been previously addressed. Recent studies have indicated that LPS decontamination can effectively remove contaminants from the surface of hair, particularly those that are hydrophilic (water soluble) in nature. However, lipophilic (oil soluble) substances will rapidly partition into the hair strands and in doing so become unavailable for decontamination (21, 22). The resulting reservoir of material may subsequently off-gas (if volatile) or remain in the hair (26). Whilst further studies are required to ascertain the toxicological significance of the residual contamination, it would seem prudent to consider removing the hair following decontamination. This is considered in more detail later (p116).

As described earlier, contaminated clothing should not be worn during LPS, as the water will carry the contaminant onto the underlying skin (p55).

Issues pertinent to the gross decontamination of C2 patients are described earlier (pp 30,32 & 33). The protocol for C1 and C2 patients on the Standard Response Pathway is summarized in Table 12.

Table 12: Ladder Pipe System (LPS) Decontamination Protocol for Patients on the Standard Response Pathway.

Step	Narrative
1	**Considerations:** • On entering the LPS corridor, most patients will experience cold shock. In addition, the sheer volume of water may induce a feeling of being unable to breathe and the natural response of the patient will be to shut their eyes. These effects may combine to cause confusion, disorientation and loss of compliance in a proportion of patients. Therefore, **at least one first responder should remain in the corridor at all times** to provide immediate assistance if required. • Remain alert for patients who adopt a hunched posture, with head facing down – this is common and will reduce the effectiveness of the LPS protocol. • The LPS corridor is noisy and so all verbal communication will need to be loud and repetitive. Use hand signs where possible to supplement verbal instructions. • Patients may attempt to walk straight through the decontamination corridor and so vigilance by first responders is required at all times.
2	**Ensure that all patients have disrobed** and, ideally, have performed emergency decontamination. **Contaminated clothing will transfer contaminants to the underlying skin during the LPS process.**
3	**Good communication** before and during the LPS procedure is essential. • Explain what is about to happen and what the patient can do to get the most benefit from the process. • Constantly repeat instructions and provide encouragement while the patient is in the LPS corridor.
4	**Decontamination Process**: Instruct each patient to: • Start walking through the corridor (Figure 37A); at the center, stop and begin by rubbing their (1) head (hair), (2) face and (3) neck first [**at least 5 seconds**]; Figure 37B. • Rub down their shoulders, arms and upper body [**at least 5 seconds**] and, if patient is able, turn body through 360º with arms out stretched; Figure 37C. • Rub down their legs to their feet [**at least 5 seconds**]; Figure 37D. • Rub hands together and walk out of the corridor.
5	**Exit:** • If available, provide a towel or other appropriate material for patients to dry themselves (active drying; p98). ○ Treat towels and washing aids (if available) as contaminated waste and dispose of them safely. • If known, inform patients when technical decontamination will be available. • Reassure patients that the decontamination processes will reduce exposure and so will help prevent adverse health effects and prevent them from spreading contamination to friends and family.

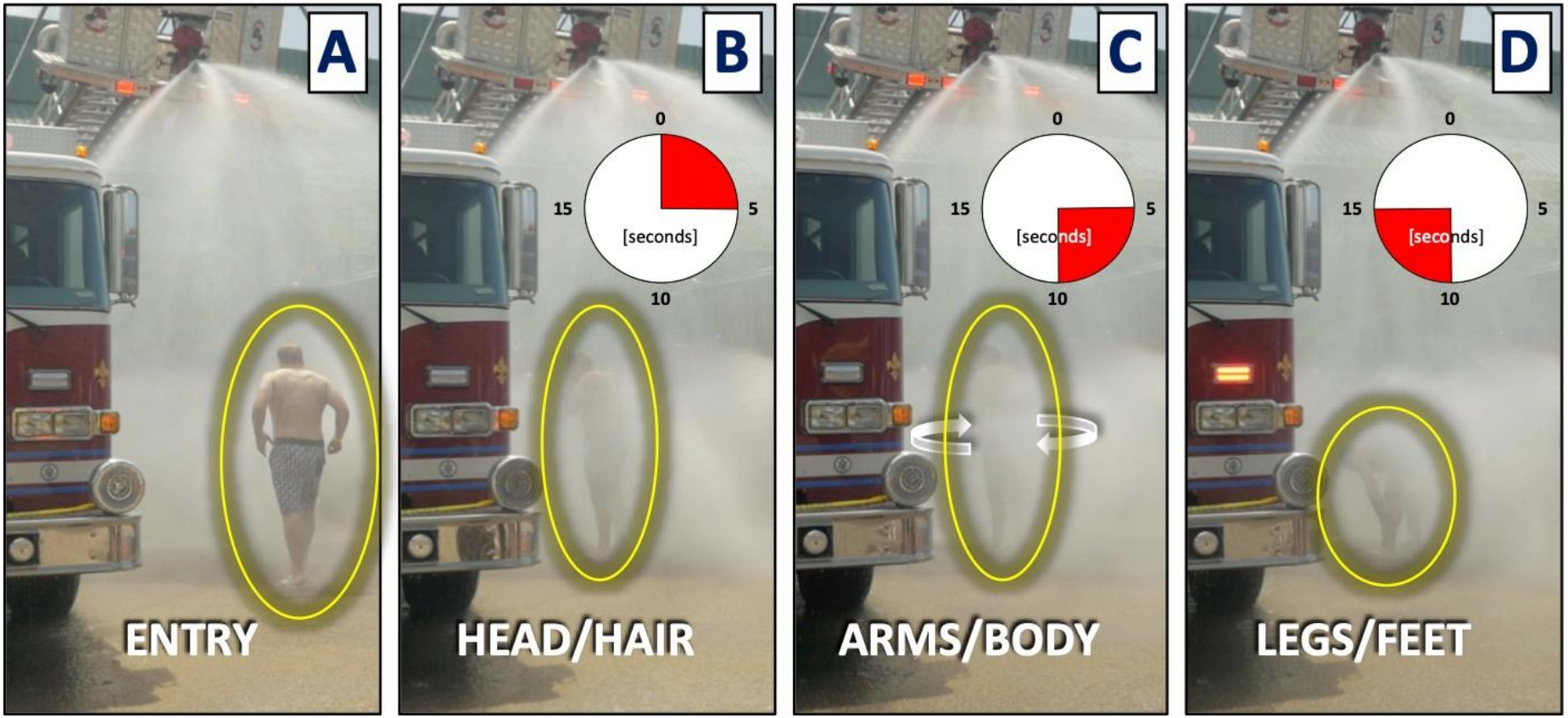

Figure 37: Standard Response Pathway Gross Decontamination Protocol. Times indicated represent the minimum allowable durations. Patients leaving the LPS corridor within 15 seconds should be asked to reverse back into the corridor to complete the minimum duration. After entering the corridor (A), instruct the patient to use their hands to wash their head, face and neck (B), followed by shoulders, body and arms (C). If possible, ask patient to turn through 360° with arms outstretched before rubbing legs and feet (D). Instruct patient to rub hands together before leaving the corridor.

Gross Decontamination Protocol for Non-Ambulatory Response Pathway

There is no quantitative data available upon which to provide evidence-based recommendations for gross decontamination of non-ambulatory patients. Therefore, C3 patients should proceed directly from emergency decontamination to technical decontamination.

Gross (Ladder Pipe System) Decontamination: Guidance

GROSS (LADDER PIPE SYSTEM) DECONTAMINATION

Key Points

- LPS decontamination is the standard method for gross decontamination.
- Is LPS decontamination necessary? Use ASPIRE decision aiding tool and professional judgement.
- LPS decontamination is time critical – establish a corridor as soon as practically possible.
- Ensure patients have fully disrobed: do not allow clothed individuals to undergo LPS decontamination.
- Ideally, emergency decontamination should be performed before LPS, but do not unnecessarily delay LPS if emergency decontamination has not been performed.
- Constantly provide instructions and communicate with patients to emphasize clinical benefits of emergency decontamination.

Basic Protocol

- Patients should enter the LPS corridor and rub themselves from top to bottom, concentrating on areas most likely to be contaminated (e.g. hair/head, face, neck, hands).
- Patient should be encouraged to remain in LPS corridor for at least 15 seconds.
- If appropriate material is available, instruct patients to undertake active drying on exiting the LPS corridor.
- Transfer patients to technical decontamination.
- Focus on compliant patients before dealing with individuals who refuse to cooperate.

Active Drying

The process of active drying relates to the removal of water from the skin and hair surfaces using an absorbent material following any wet decontamination processes.

For emergency wet decontamination, this can take the form of drying the skin with paper towels or any other available absorbent material. For decontamination processes associated with the SOR (i.e., LPS and technical decontamination) an adequate supply of towels should be incorporated into existing response plans to ensure availability during an incident (29, 36, 39, 54, 80, 82, 137, 140).

Active Drying is an Integral Part of Wet Decontamination

Active drying is a critical component of wet decontamination (137, 140), potentially accounting for more than half the contaminant removed by wet decontamination processes (28). This effect can be readily observed in the domestic environment: towels used to dry hands after washing with soap and warm water become visibly dirty – the soap and water represent one part of the cleansing process, with towel drying being the second component. Therefore, active drying should be considered an integral part of any wet decontamination process.

Given that active drying removes a considerable proportion of chemical contaminants, all materials used to dry patients must be treated as hazardous waste and disposed of in accordance with local legislation.

Active Drying Protocol

A process of active drying has been evaluated that does not cause detectable transfer of contaminant across the hair or skin surfaces (30). Although not subject to optimization, the method adopts a common-sense approach starting with the face, then the hair/head and moving systematically down the body (Figure 38). The head should be tilted back when drying hair to avoid transfer of any residual contaminant from the hair to the face.

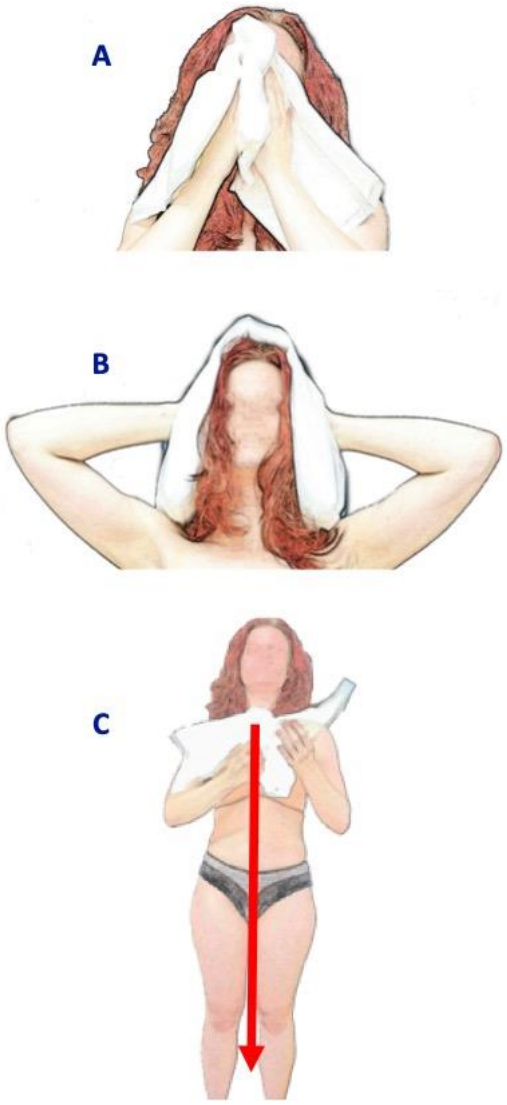

Figure 38: Process for active drying. Start with the face (A), tilt head back to dry the hair/head (B), then progressively move down the body (C).

Active Drying: Guidance

ACTIVE DRYING

Planning

- Provision of towels should be addressed when formulating an incident response plan.

Key Point

- Active drying represents a critical stage in the decontamination process and so it is essential that towels or other suitable materials are available to patients following wet decontamination procedures.

Basic Protocol

- Following any form of wet decontamination, provide towel or any available absorbent material.
- Dry from top to bottom. Tilt head back when drying hair.
- Used drying materials should be treated as hazardous waste.

Technical Decontamination

The primary objective of technical decontamination is "to reduce a patient's contamination to a level that is as low as possible in order to minimize the potential for secondary contamination of responders, receivers, other people, equipment, and facilities" (29). Technical decontamination is also referred to as "mass decontamination", "thorough decontamination", "secondary decontamination", "clinical decontamination" and "medical decontamination". Historically, technical decontamination originally referred to the decontamination of incident response vehicles, and PPE (141). For the purpose of this guidance document, technical decontamination is the third stage of the Triple Protocol for mass patient decontamination and requires deployment of functional decontamination units as part of the specialist operational response (Figure 39).

Figure 39: Standard US Technical Decontamination Unit. In this example, the unit is assembled from the ground sheet up (A) and is an inflatable structure erected with compressed air. All components of the unit are deployed in a specialist response trailer (B; rear view of interior). The inflated structure can be tethered to ground pegs or weights (C). The water in this unit did not contain a detergent dosing unit and so washcloths were doused with liquid soap by Fire Department officers (D; circled area). The water hoses in this unit were ceiling-mounted (D; boxed area) and manually activated by patients via spray guns. The shower water was pre-heated using a thermostatic boiler (not shown), fed from a fire hydrant.

It should be recalled that the need to progress to technical decontamination should be carefully considered. The ASPIRE decision-aiding tool and/or triage can assist in identifying the need to perform technical decontamination.

Standard Response Pathway for Technical Decontamination

A previous program of work has identified optimal parameters for technical decontamination (51, 137, 140, 142, 143) and is referred to as the "ORCHIDS protocol". This optimized protocol makes use of inexpensive, practical improvements. For example, the use of a washcloth (active washing) can improve decontamination effectiveness by ~20% (80). The duration of showering should be no longer than 90 seconds (144). This is partly to offset the "rinse-in" or "wash-in" effect associated with enhanced dermal absorption of chemicals (115, 145). In practice, extending the shower duration has no discernable effect on decontamination efficacy (80, 146). Various field trials have demonstrated that the ORCHIDS protocol is at least as effective as existing national protocols in removing contaminants whilst improving patient throughput (142). A useful mnemonic for technical decontamination is "WASHED" (Table 13).

Table 12: The "WASHED" mnemonic for technical decontamination performed as part of the Specialist Operational Response.

W	**Warm Water:** shower water temperature should be between 35ºC (95ºF) and 40ºC (104ºF) to ensure optimal removal of contaminants.
A	**Aid:** the use of a washing aid (e.g., washcloth or sponge) will improve the removal of contamination by 20% during the showering process. Washing aids should be single-use and considered as hazardous waste after use.
S	**Soap:** The use of a detergent has been shown to assist decontamination of lipophilic (oily) substances. Where available, use a metered dosing system to add liquid detergent to shower water at a concentration of 0.1–0.5% (v/v). Alternatively, place ~10 mL of liquid soap or detergent directly onto the washing aid immediately prior to use.
H	**Head to toe:** Instruct patients to wash from the top of the head down to their feet. The head should be tilted back during hair washing to avoid transfer of contamination onto the face.
E	**Expedite:** In order to avoid the "wash-in" effect (which can enhance dermal absorption of certain contaminants), shower for **no longer than 90 seconds**. Ideally, 1 minute with soapy water followed by ½ minute of rinsing with water only.
D	**Drying:** active drying with a towel or other appropriate material is a critical step for removing many chemical contaminants. As with washing aids, used towels must be treated as hazardous and disposed of in accordance with local regulations.

Technical Decontamination: Practical Considerations and Potential Risks

There is some data to suggest that manually-operated, ceiling-mounted spray systems (e.g., Figure 39) may reduce a patient's focus on decontamination of the head and hair (25, 30). In contrast, automated systems (where the flow of water is externally controlled and delivered via nozzles placed at varying heights around each patient) are more likely to deliver a whole-body shower. Therefore, responders supervising technical decontamination in a manually-operated system need to ensure that patients focus attention on their hair, head and face.

Several types of technical decontamination unit have water boilers with an integral, metered dosing system to introduce detergents at a set concentration for set periods during a shower cycle. In the absence of such an appliance, approximately 10 mL of detergent can be added directly to the washing aid (e.g., washcloth) by responding officers (as demonstrated in Figure 39D).

Some C2 patients may experience difficulties when performing technical decontamination (p30, 33) and so assistance may be required.

Technical decontamination units offer a greater degree of privacy than LPS or emergency decontamination because opaque enclosures are used. However, such designs may introduce an inhalational risk from accumulation of toxic vapors within the decontamination structure: significant off-gassing of a medium volatility chemical warfare agent simulant (methyl salicylate) has been demonstrated during 90-second technical decontamination cycles (28). The off-gassing is significantly reduced if technical decontamination is preceded by other forms of decontamination: Figure 40. Therefore, detection, identification and monitoring (DIM) equipment should available to monitor the concentration of chemical vapors within technical decontamination units. In addition, the unit should be frequently ventilated during use, although this may impact on patient throughput.

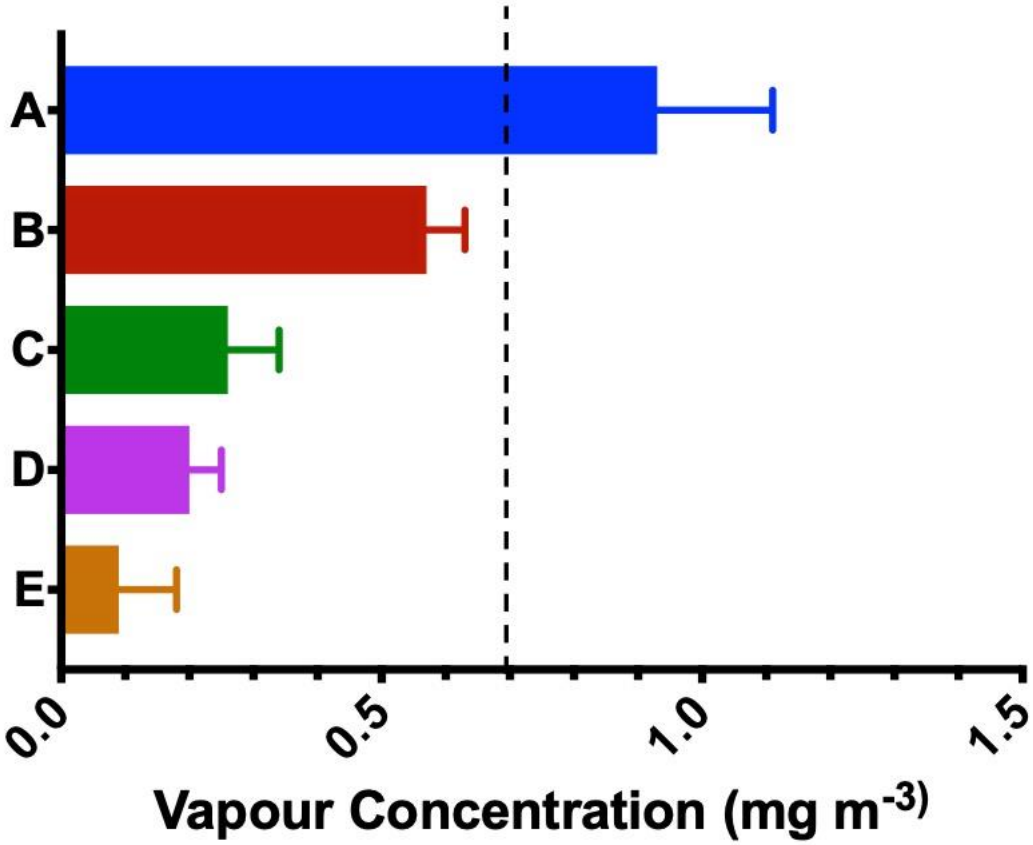

Figure 40: Average concentration of a mid-volatility chemical warfare agent simulant (methyl salicylate, expressed as mg m^{-3}, with standard error of mean for n=10 subjects) experienced by patients in different treatment groups (A–E) within a technical decontamination unit during a human volunteer study (28). Treatment groups were: (A) Technical Decontamination only; (B) Dry Decontamination followed by Technical Decontamination; (C) Combined Dry, LPS (without towel drying) and Technical decontamination; (D) LPS decontamination (without towel drying), followed by Technical Decontamination; and (E) the Triple Protocol of combined Dry, LPS (with towel drying) and Technical Decontamination. To put these data into context, the IDLH (immediately dangerous to life and health) value for sulfur mustard is 0.7 mg m^{-3} (147); indicated by the dotted line. This emphasizes the need to perform technical decontamination as part of the Triple Protocol, as the vapor hazard decreases with increasing number of decontamination stages.

Non-Ambulatory Response Pathway for Technical Decontamination.

There is some limited evidence to support a recommended technical decontamination protocol for the non-ambulatory response pathway, based on a study performed under controlled conditions (52). However, further work is required to evaluate the process under more realistic conditions. As with dry and LPS decontamination, technical decontamination is more resource intensive than the standard protocol but can (theoretically) be performed in ~4 minutes (Table 13).

Table 13: Technical Decontamination Protocol for Patients on the Non-Ambulatory Response Pathway (52).

Step	Narrative
1	**Initial setup:** • Patient should arrive disrobed with any immediately life-threatening injuries under control. • A minimum of four* responding officers are required (D-1 through D-4; Figure 41). • Each officer should have access to a washing aid (e.g., sponge or facecloth). • Officers D-1 and D-2 focus on the head and uppermost body areas (particularly the hair, head, face and neck).
2	**Rinse-wipe-rinse front of body surfaces [90 seconds]** • D-2 through D-4: rinse down all accessible patient surfaces (Figure 42A) for 30 seconds. • D-2 through D-4: wash all accessible patient surfaces (Figure 42B) for 30 seconds. • D-2 through D-4: rinse down all accessible patient surfaces (Figure 42C) for 30 seconds. • D-1: support head and neck at all times and monitor patient's airways/breathing and protect airways (Figure 42D).
3	**Controlled rotation of patient onto side** • D-2 and D-4: prepare patient for rotation by crossing arm across chest and moving ipsilateral foot towards body to raise knee (Figure 43A). • D-1: support head and neck. • D-2 through D-4: rotate patient onto contralateral side in a single, coordinated movement, ensuring full physical control at all times (Figure 43B). • Following rotation, patient should be stabilized primarily by D-3, with D-1 maintaining head and neck support (Figure 43C). • D-2 and D-4 should now be able to remove hands from patient.
4	**Rinse-wipe-rinse back of body surfaces [90 seconds] with Board Decontamination.** • D-2 through D-4: rinse down all accessible patient surfaces (Figure 44A) for 30 seconds. • D-2 through D-4: wash all accessible patient surfaces (Figure 44B) for 30 seconds. • D-2 through D-4: rinse down all accessible patient surfaces (Figure 44C) for 30 seconds. • D-2 and D-4 wash and rinse the spinal board to remove contamination. • D-1: support head and neck at all times and monitor patient's airways/breathing and protect airways.

Table 13 (continued)

Step	Narrative
5	**Controlled reverse rotation of patient** This is the opposite of Stage 3: • D-2 through D-4: perform controlled rotation of patient back to original position (Figure 45A&B). Move patient's arm from chest to side of body and guide knee back onto spinal board (Figure 45C). • D-3: wash and rinse spinal board to remove any contamination.
6	**Perform final rinse of accessible surfaces [10 seconds]**: Figure 46A, ensuring patient's airways are protected from water (Figure 46B).

*When non-ambulatory technical decontamination is being performed, it would be advisable for an additional responding officer to be present within audible range of the four decontamination officers to provide timed instructions for each stage of the process.

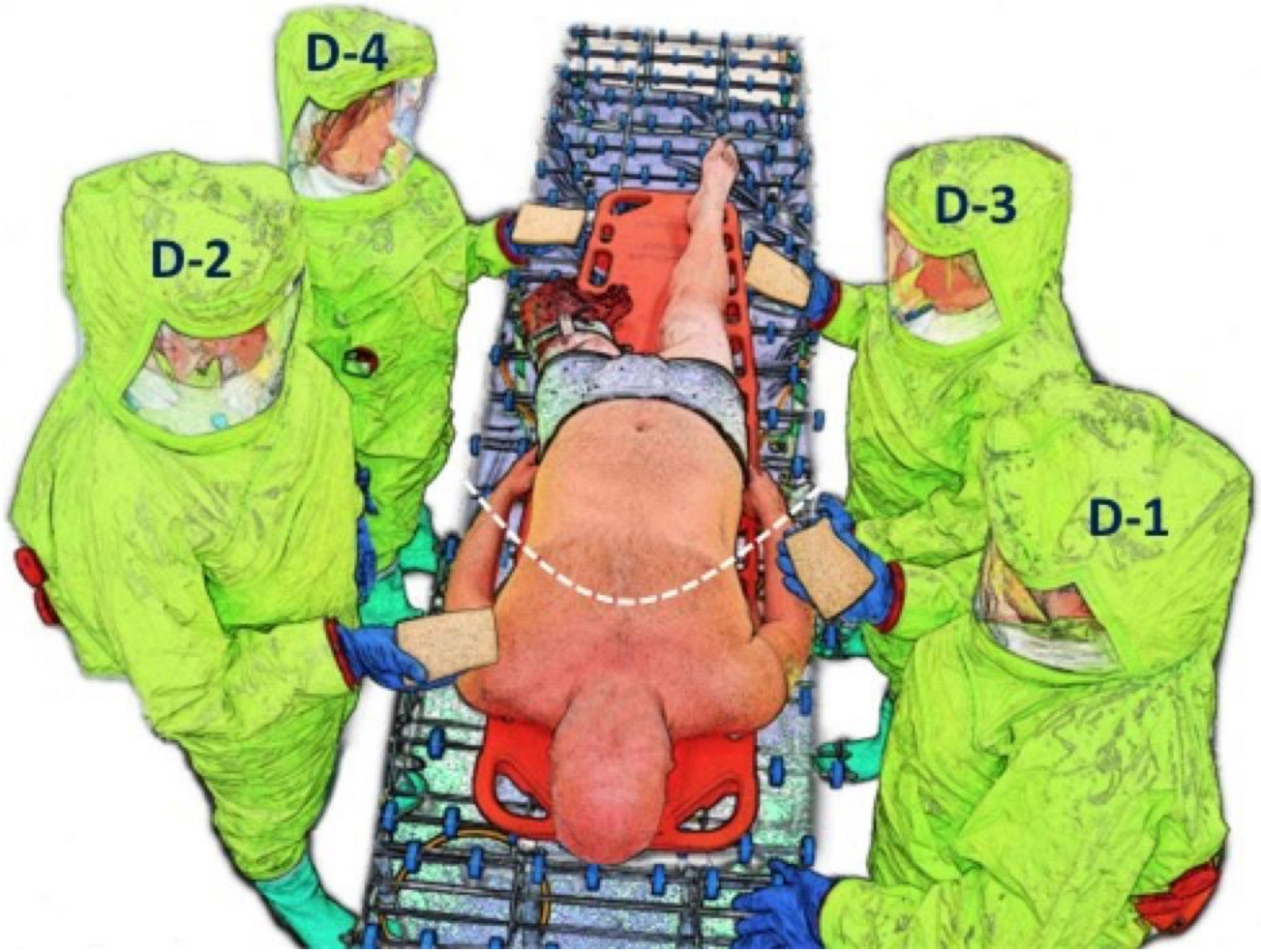

Figure 41: *Non-ambulatory Technical Decontamination Protocol – Initial positions for responding officers (D-1 through D-4). The dotted line across the chest approximates to the body areas cleansed by responders D-1 & D-2 (upper body) and D-3 & D-4 (lower body areas).*

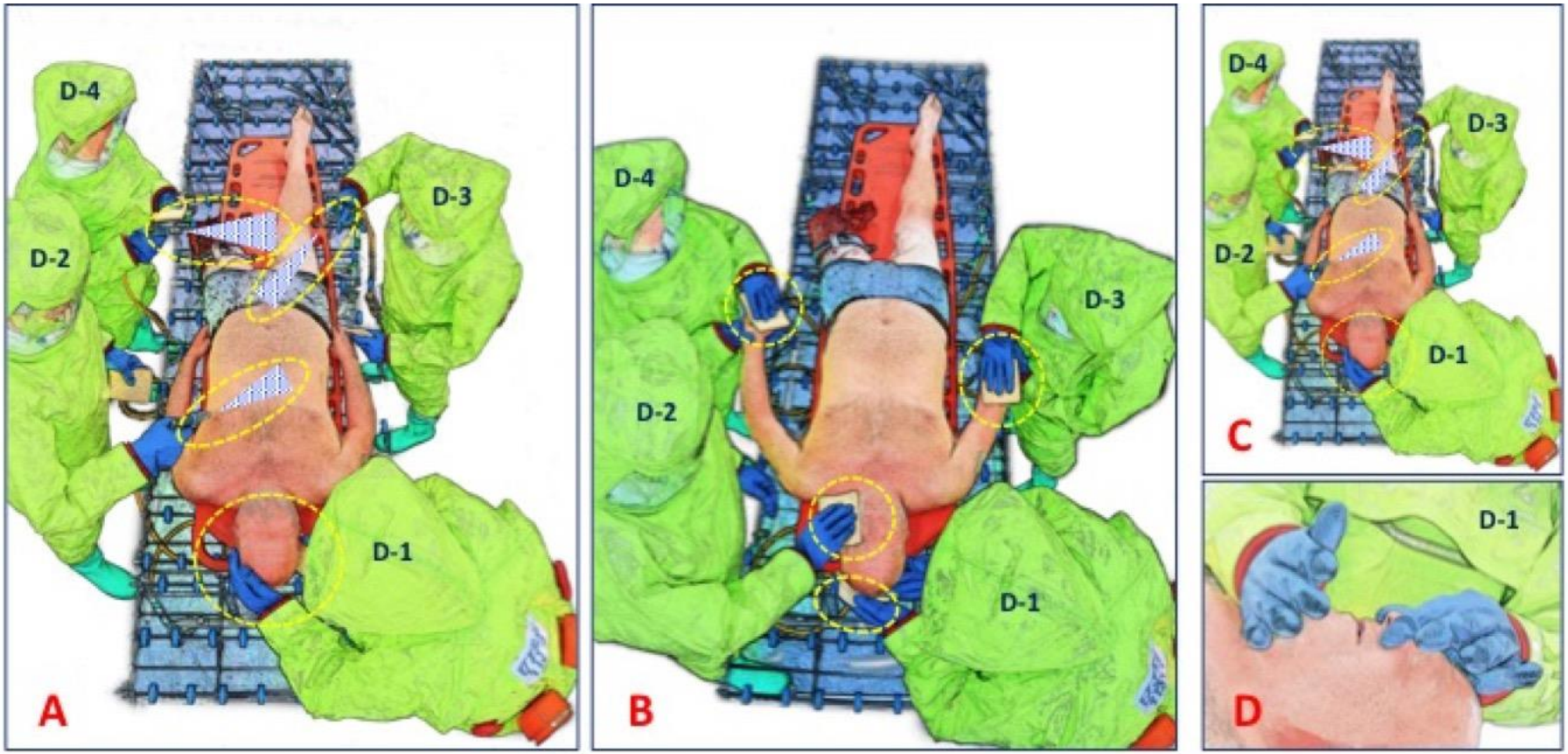

Figure 42: Non-ambulatory Technical Decontamination Protocol – use the rinse-wipe-rinse technique for front of body. It is assumed that patient disrobe has taken place (during the emergency decontamination stage). Left Image [A]: Responder D-1 supports the head/neck. Responder D-2 rinses the upper body, paying particular attention to head, face and neck. Responders D-3 & D-4 rinse down the lower body areas. Middle Image [B]: Responder D-3 wipes the upper body, focusing on head, face, neck, shoulders and upper arms. D-1 washes head if patient circumstances permit. Responders D-3 and D-4 wash lower body, focusing on hands, arms and other likely exposed areas. Top Right Image [C]: repeat rinse step. Bottom Right Image [D]: when rinsing head and face, D-1 responder protects airways to prevent inhalation of water. In this example, the nose has been pinched and the face shielded from splashes.

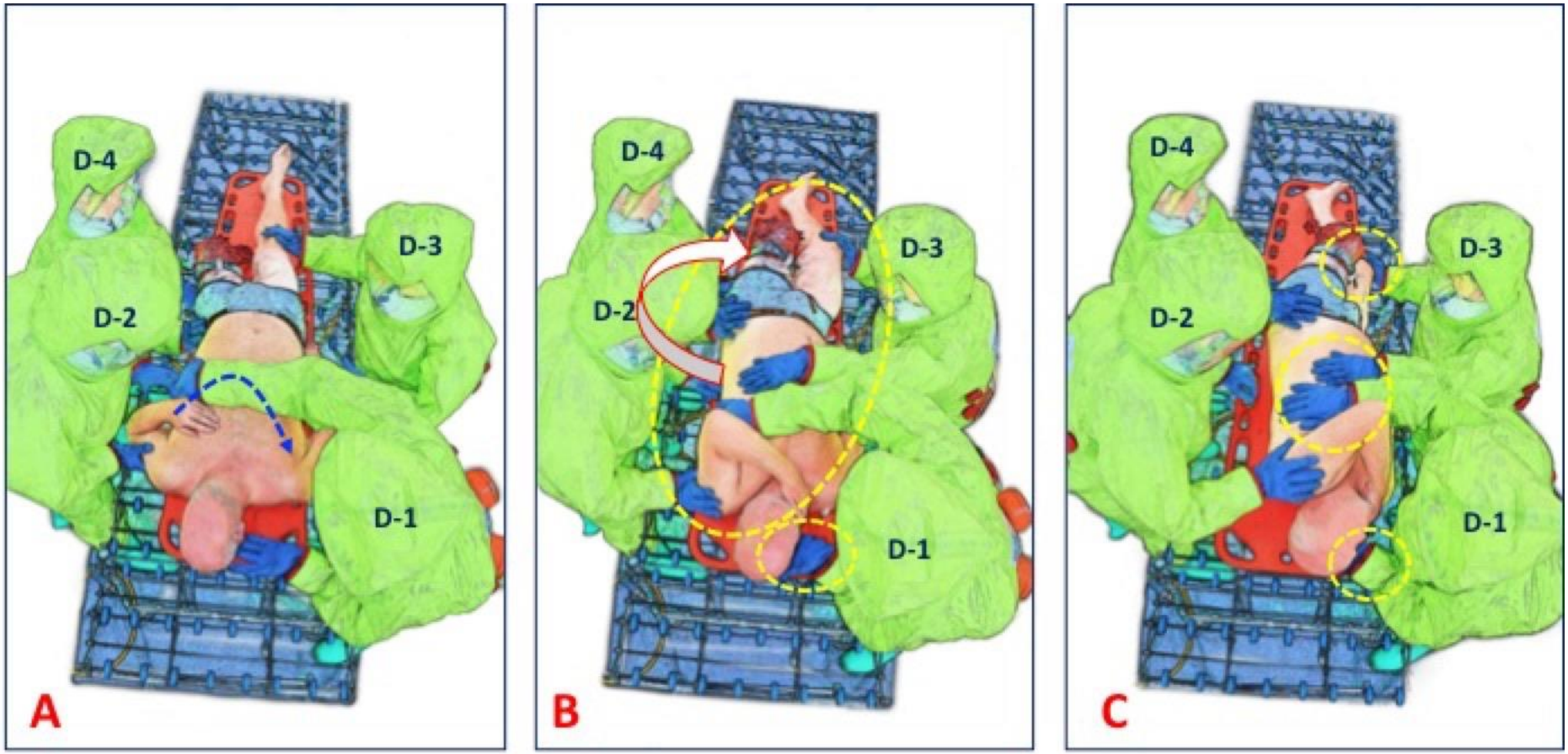

Figure 43: Non-ambulatory Technical Decontamination Protocol – Controlled Rotation of Patient. Left image [A]: In this example, the patient's left arm is placed across the chest. The left knee (missing in this example) would be raised by bringing the left foot towards the body. Middle image [B]: D-2–D-4 place hands on patient and perform a coordinated roll of the patient towards D-1 and D-3. D-1 supports head and neck. Right image [C]: Patient is rotated through 90°, under constant control by D2–D-4. Patient position should be stable and under the full control of D-1 and D-3 before proceeding to next step.

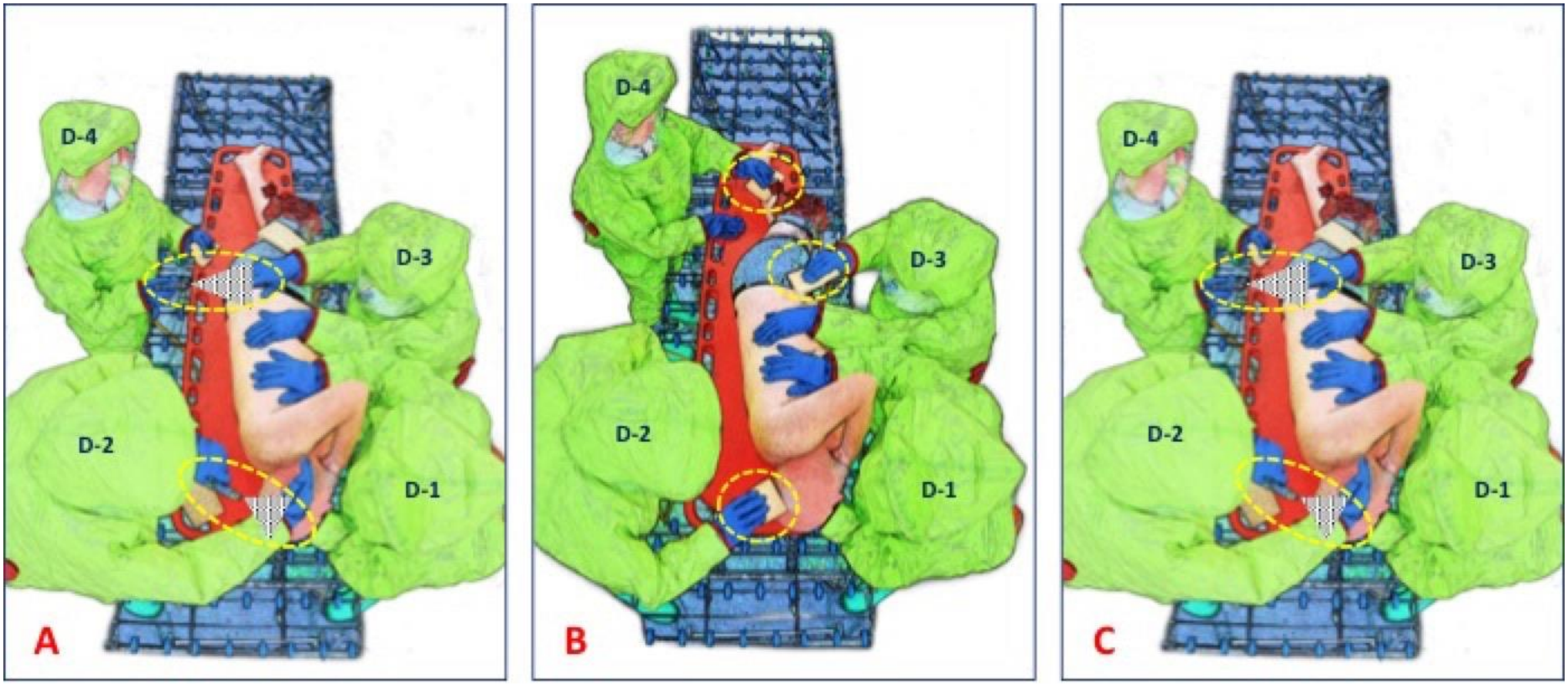

Figure 44: Non-ambulatory Technical Decontamination Protocol – Rinse-Wipe-Rinse technique for back of body. Left Image [A]: Responder D-1 supports the head/neck. Responder D-2 rinses the upper body, paying particular attention to hair/back of head and neck. Responders D-3 & D-4 rinse down the lower body areas. Middle Image [B]: Responder D-3 wipes the upper body, focusing on hair/back of head, face, neck, shoulders and upper arms. D-2 supports head and neck, washing head if patient circumstances permit. Responders D-3 and D-4 wash lower body, focusing on hands, upper arms and other likely exposed areas. Right Image [C]: repeat rinse step.

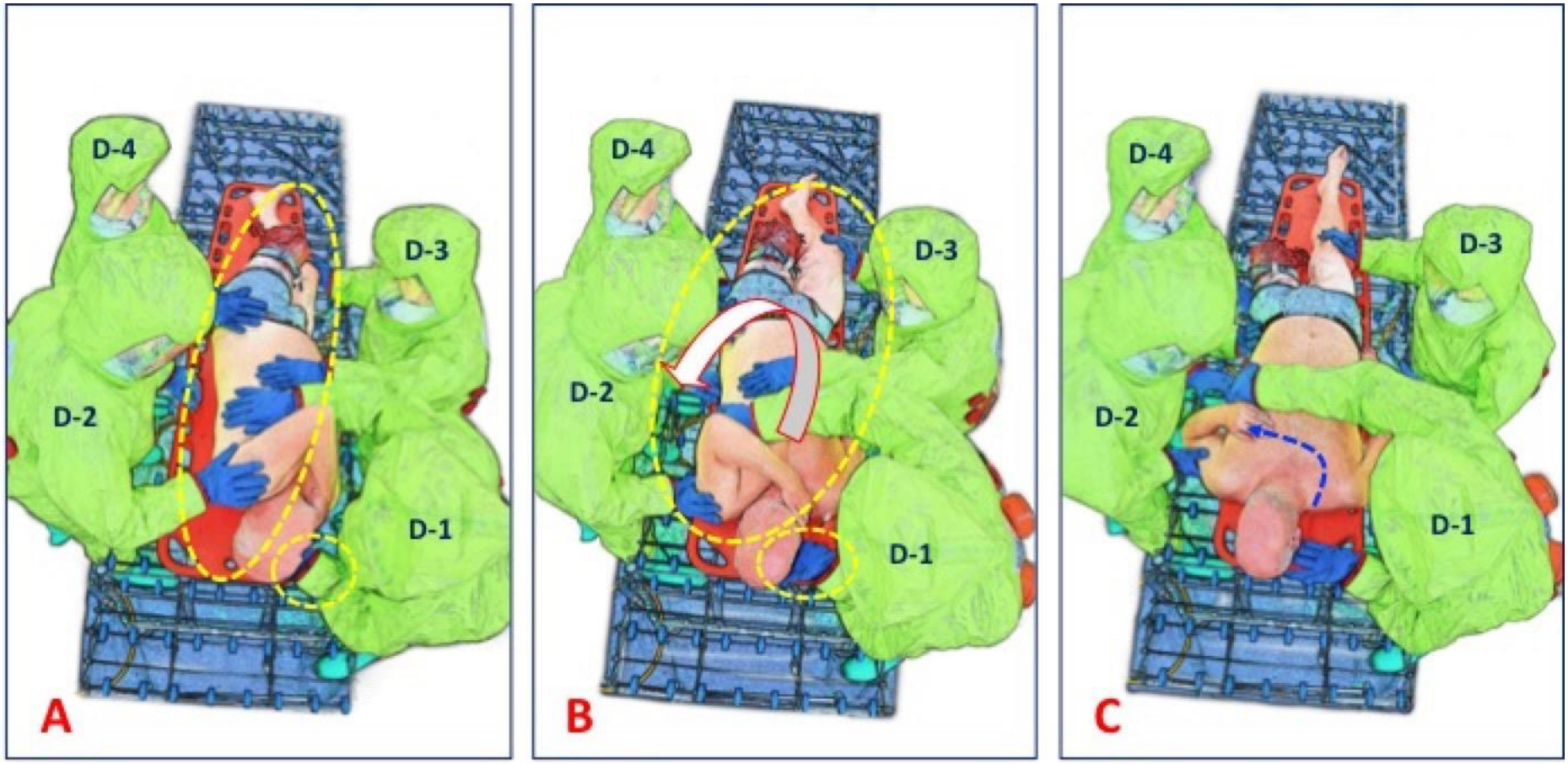

Figure 45: Non-ambulatory Technical Decontamination Protocol – Controlled Reverse Rotation of Patient. Left Image [A]: D-2–D-4 place hands on patient and perform a coordinated roll of the patient back towards D-2 and D-4. Middle image [B]: Patient is rotated through 90º, under constant control by D2–D-4. Right image [C]: D-2 and D-3 move arm and ipsilateral leg back to original position.

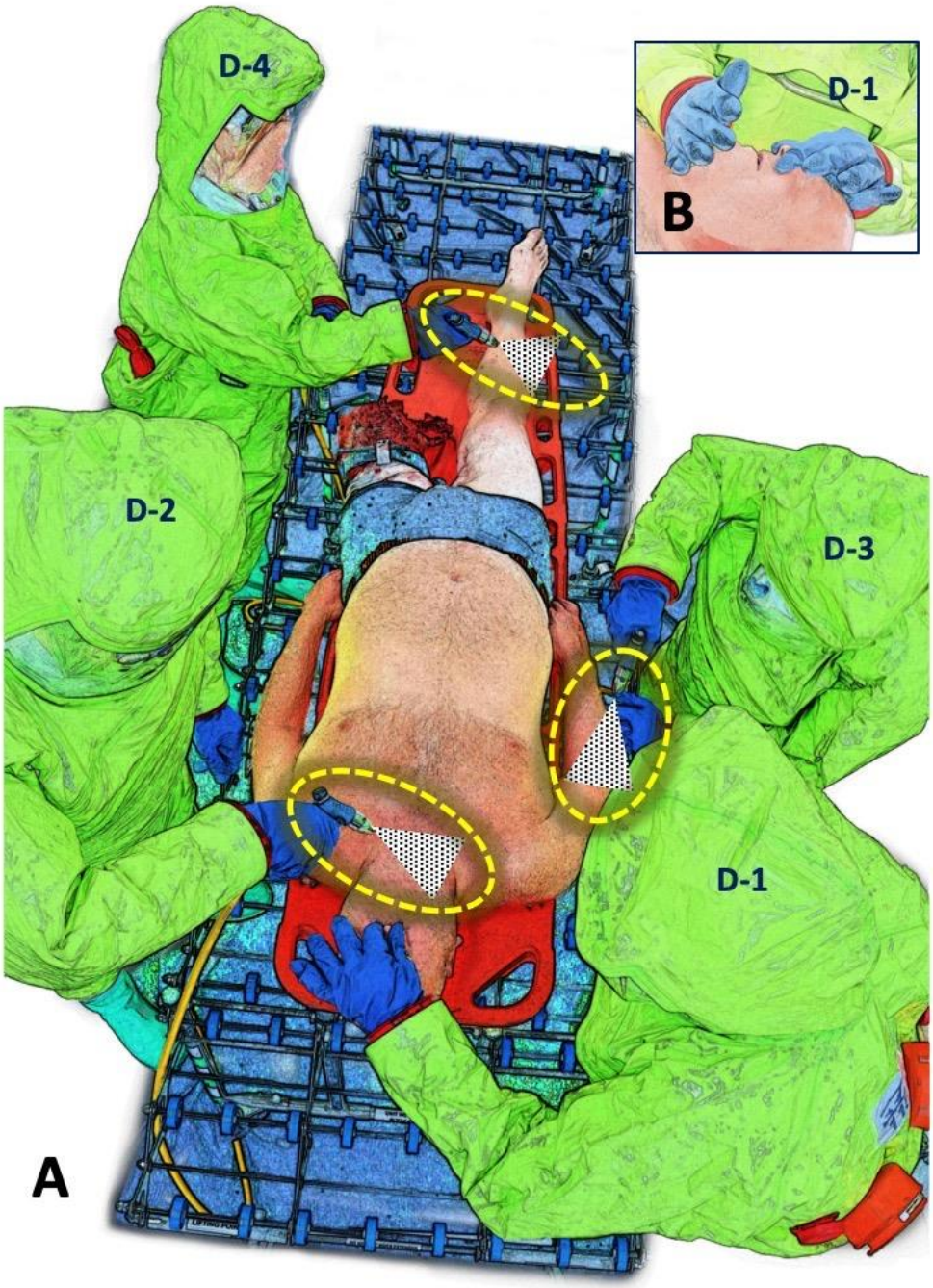

Figure 46: Non-ambulatory Technical Decontamination Protocol – Final Rinse (A) if necessary. D-1 protects airways from splashes or direct spray to the face, using shielding posture (B).

TECHNICAL DECONTAMINATION

Planning

- Planning should include the provision of resources that will optimize the technical decontamination process (e.g. disrobe and re-robe kits, wash cloths, soap/detergent, towels).

Key Points

- Technical decontamination should be performed following Emergency and LPS decontamination, as part of the "Triple Protocol".
- Focus on compliant patients before dealing with individuals who refuse to cooperate.

Basic Protocol

- If disrobing of C1 and C2 patients has not already taken place, provide disrobe packs and instructions on how to safely remove clothes.
- The optimized parameters for technical decontamination include a shower water temperature of 35–40ºC (95–104ºF), duration of 60–90 seconds (maximum), addition of mild detergent to the shower water and the provision of a washcloth for each patient.
- C1 and C2 Patients should be instructed to wash from head to toe. C3 patients should be treated by trained first responders using the non-ambulatory technical decontamination protocol.
- All patients should actively dry following decontamination.
- Emergency responders should be aware of the potential for the accumulation of vapor within technical decontamination units.
- Washcloths should be treated as contaminated waste.

Summary: Standard Response Pathway

The salient features of the standard response pathway are presented in Figure 47.

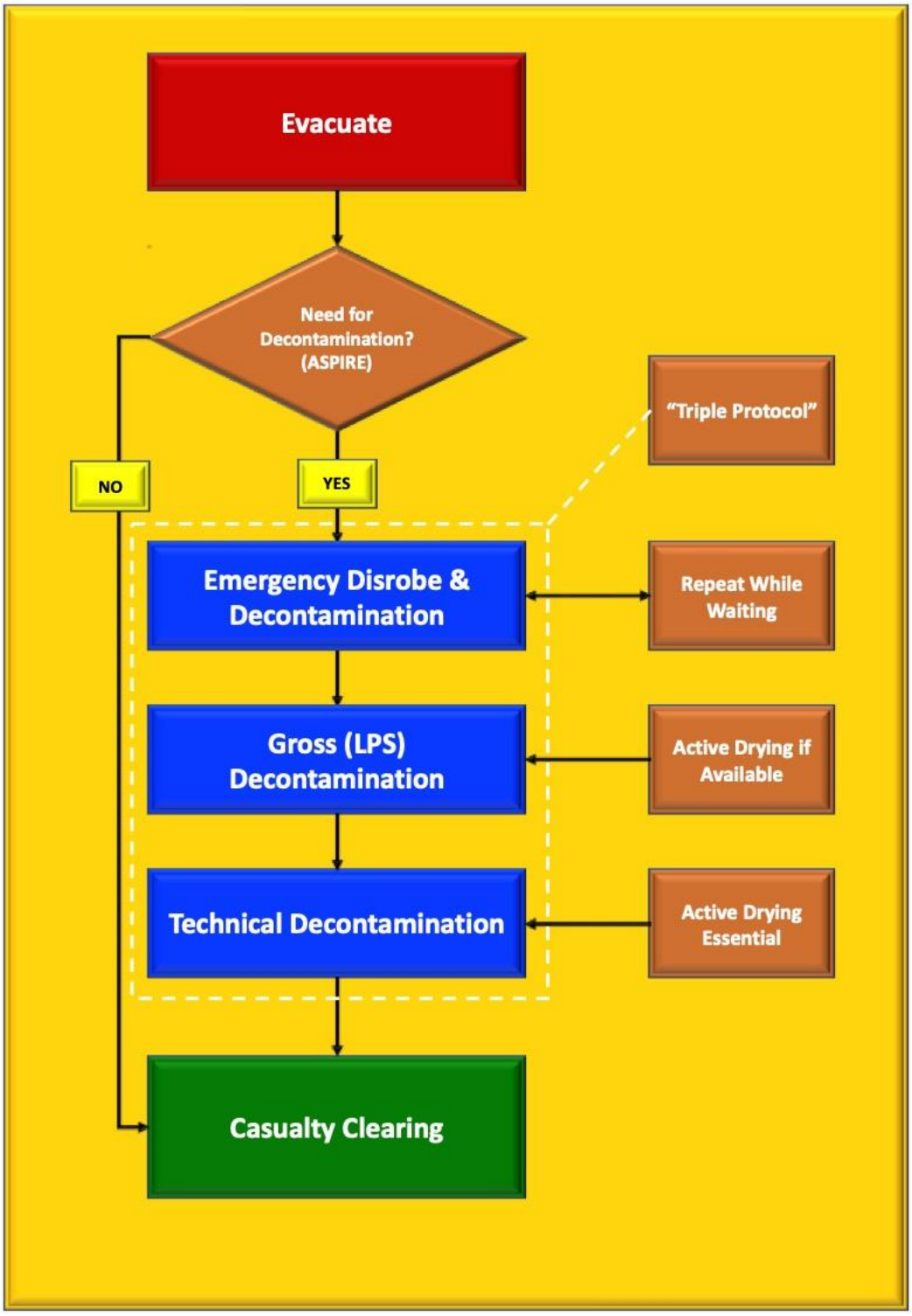

Figure 47: Summary of the Standard Response Pathway for C1 Patients and C2 Patients (unless sufficient resources are available to provide a Non-ambulatory Response Pathway for C2 patients who require a greater level of assistance).

Summary: Non-Ambulatory Response Pathway

The salient features of the standard response pathway are presented in Figure 48.

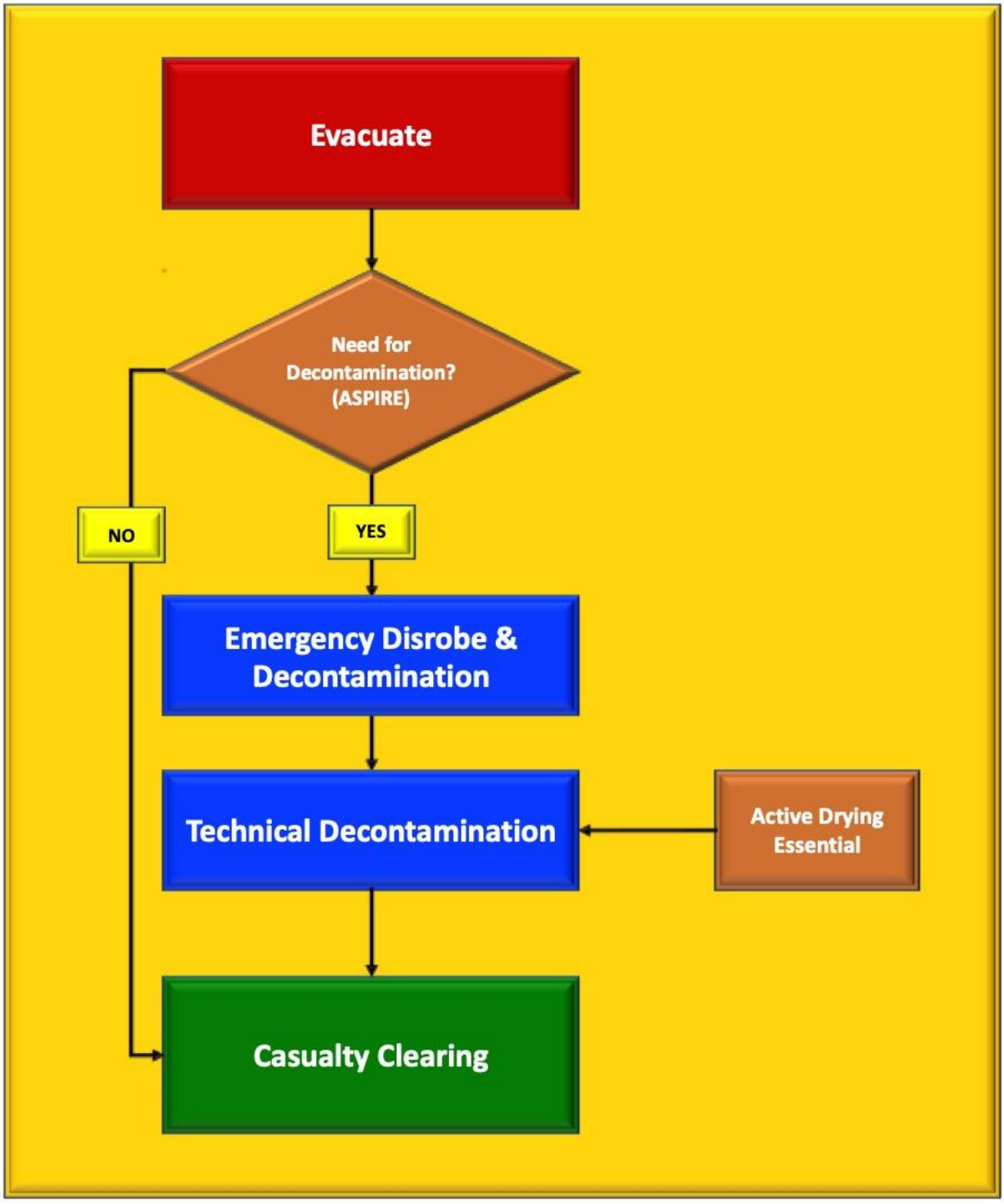

Figure 48: Summary of the Non-ambulatory Response Pathway for C3 Patients.

Hair: Important Post Decontamination Actions

Contaminated Hair

Historically, research has focused on skin decontamination and relatively few studies have addressed contaminated hair. Scalp hair represents one of the most exposed surfaces of the human body and so will be disproportionately contaminated following aerial delivery of a liquid contaminant. Furthermore, hair provides a substantial degree of protection for the underlying scalp skin (20, 23, 31, 148). Thus, it is essential that effective methods to decontaminate hair are available and that any further necessary actions or precautions are identified.

A previous study demonstrated that showering hair with water or detergent solution 60 mins post exposure was more effective against VX when preceded (at 30 minutes) by dry decontamination (149). Other investigations, using a range of contaminants, have indicated that lipophilic chemicals rapidly partition into the hair (20) and so become resistant to water-based decontamination (22).

Recent Studies

Residual hair contamination following the Triple Protocol of dry, LPS and technical decontamination has been studied further to determine (1) the extent to which chemicals form a reservoir within the hair, (2) how delayed decontamination affects extraction of the reservoir using solvents or detergent solutions, (3) the off-gassing kinetics of chemicals from the hair reservoir and (4) characterization of the molecular interactions between chemicals and hair to determine reversible or irreversible binding (26). The salient outcomes of the study demonstrated that:

- The effectiveness of the Triple Protocol for decontamination of lipophilic contaminants from hair decreased rapidly, with only marginal efficacy observed 5 minutes post exposure.
- The predominant fraction (~65%) of the applied dose of lipophilic materials following Triple Protocol decontamination was recovered from within the hair by solvent extraction.
- Water or detergent solutions were relatively ineffective at extracting the hair reservoir of lipophilic contaminants.
- Off-gassing of a medium volatility, lipophilic chemical was extensive (>60% of the applied dose) and prolonged (detectable 5 days post exposure; Figure 49).
- There were no detectable indications of irreversible (strong) bond formation between the contaminants and the hair.

Provisional Recommendation for Contaminated Hair

In summary, hair contaminated with lipophilic chemicals (which may include chemical warfare agents such as HD, VX and GD) cannot be adequately decontaminated and may pose a contact and/or inhalation hazard. Whilst independent verification of these outcomes is required, caution is clearly warranted. Therefore, it is recommended that consideration be given to removing hair in circumstances where the following criteria are met:

1. Contamination is known to have occurred.
2. The contaminant is known to be toxic.
3. Residual contamination has been confirmed following the Triple Protocol using available DIM equipment.

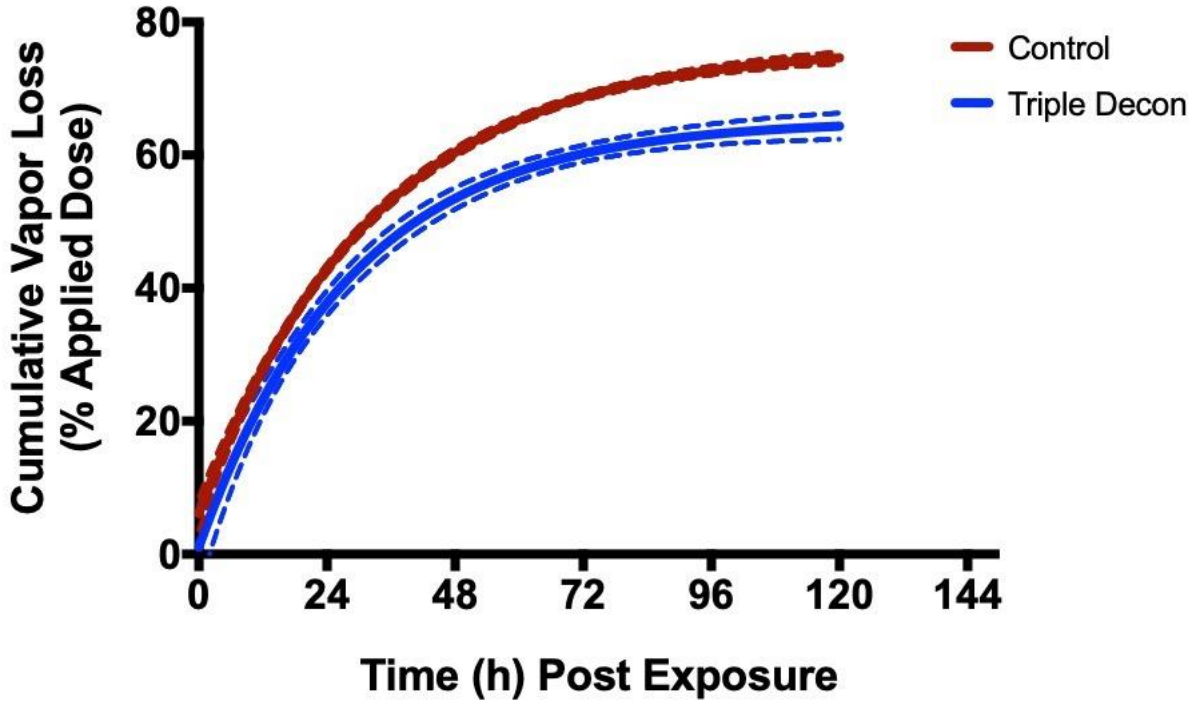

Figure 49: Off-gassing of a medium volatility lipophilic liquid chemical (methyl salicylate) from hair that was untreated (control) or following Triple Protocol decontamination (combined dry, LPS and technical decontamination) performed 20 minutes post exposure, expressed as the cumulative recovery of vapor as a percentage of the original applied dose of liquid. Dotted lines indicate 90% confidence intervals. Despite undergoing Triple Protocol decontamination, there remains a significant reservoir of material within the hair which results in off-gassing of material on a similar order of magnitude to non-decontaminated hair.

Summary & Recommendations

The guidance presented in this document is predominantly based on technical evidence and requires two operational changes from traditional practices:

- An understanding that the IOR is time critical. Evacuation, disrobe, and emergency decontamination must be completed as rapidly as possible in the likely absence of any specialist resources (such as an LPS decontamination corridor and technical decontamination units).
- In order to reduce the complexity of dealing with a range of potential issues, patients should initially be categorized for one of two responses: Standard or Non-ambulatory. The former accommodates individuals who are able to understand and perform instructions (C1 patients) or those who are either unable to understand instructions or unable to perform activities without accommodations or assistance (C2 patients). The non-ambulatory pathway is for patients who are unresponsive, have life-threatening injuries or require extensive accommodations or assistance (C3 patients), but can also accommodate C2 patients if or when sufficient resources become available.

The salient features of the PRISM response processes are summarized in Figure 50.

The revised incident response process will pose new challenges for those engaged in planning and preparing for Hazmat and CBRN incidents and recommendations for further work include:

- The development of improved methods of communication.
- Provision of auxiliary items (e.g., washcloths, towels).
- Processes for handling potentially contaminated waste (previously considered to be clean).
- Clearly, further work is required to develop more effective forms of communication and decontamination procedures for C2 patients and to identify which auxiliary items (e.g. medical equipment, service animals, mobility aids) can be successfully decontaminated as part of the incident response process.

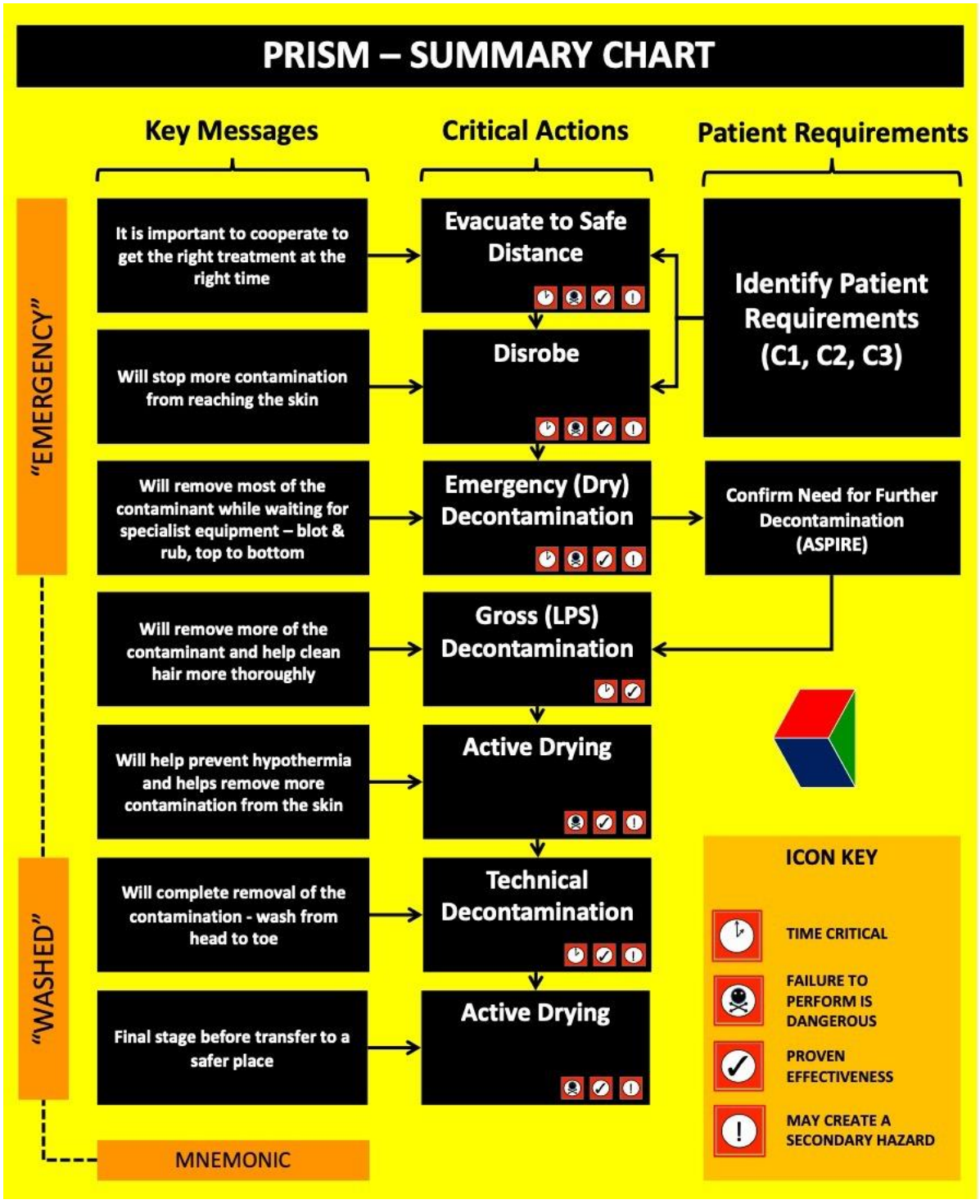

Figure 50: Salient features of the PRISM Primary Operational Response, encompassing the Initial Operational Response (IOR) and Specialist Operational Response Phases.

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Index

Annex A: ΔH_{evap} values for a range of common chemicals

The following values are provided for use in conjunction with the ASPIRE Ready-Reckoner (Main text; Figure 6). The ΔH_{evap} values are dependent on the temperature at which the experimental measurements were performed. Small differences in ΔH_{evap} should not adversely affect the outcome of the Ready-Reckoner.

Substance Name	CAS Number	Heat of Vaporization (ΔH_{evap}; kJ mol^{-1})
1-Butyl Mercaptan	109-79-5	32
1-Hexanol	111-27-3	32
1-Methylnaphthalene	90-12-0	46
1-Octanethiol	111-88-6	42
1,1-Dichloroethane	75-34-3	31
1,1-Dichloroethylene	75-35-4	27
1,1-Difluoroethane	75-37-6	19
1,1-Difluoroethene	75-38-7	10
1,1-Dimethylhydrazine	57-14-7	34
1,1,1-Trichloroethane	71-55-6	33
1,1,2,2-Tetrachloroethane	79-34-5	46
1,2-Dibromo-3-chloropropane	96-12-8	42
1,2-Dichloroethane	107-06-2	35
1,2-Dichloroethylene	540-59-0	32
1,2-Dichloropropane	78-87-5	36
1,2-Diphenylhydrazine	122-66-7	47
1,2-Propanediol Dinitrate	6423-43-4	64
1,2-Propylene Oxide	75-56-9	28
1,2,4,5-Tetrachlorobenzene	95-94-3	61
1,2:3,4-Diepoxybutane	1464-53-5	36
1,3-Butadiene	106-99-0	21
1,3-Dichloropropene	542-75-6	33
1,3-Dinitrobenzene	99-65-0	97
1,3-Dioxolane	646-06-0	34
1,3-Pentadiene	504-60-9	28
1,3,5-Trinitrobenzene	99-35-4	70
1,4-Dioxane	123-91-1	39
1,6-Hexanediol Diacrylate	13048-33-4	54
2-Chloroethanol	107-07-3	46
2-Ethyl-1-hexanol	104-76-7	49
2-Hexanone	591-78-6	43
2-Mercaptoethanol	60-24-2	46
2-Methoxyethanol	109-86-4	38
2-Nitroaniline	88-74-4	65
2-Nitropropane	79-46-9	41
2-Pentanone	107-87-9	38
2-Pentyl Acetate	626-38-0	37
2-Pyrrolidinone,1-ethenyl-	88-12-0	45
2-Xylene	95-47-6	43
2,2-Dimethylbutane	75-83-2	28
2,2-Dimethylpropane	463-82-1	22
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	65

2,4-Dichlorophenoxyacetic acid	94-75-7	62
2,4-Dinitrophenol	51-28-5	58
2,4-Dinitrotoluene	121-14-2	77
2,4-Lutidine	108-47-4	39
2,4-Toluene Diisocyanate	584-84-9	60
2,4,6-Trinitrotoluene	118-96-7	87
2,6-Toluene Diisocyanate	91-08-7	60
3-Bromo-1-propyne	106-96-7	27
3-Chloro-1,2-dihydroxypropane	96-24-2	52
3-Nitroaniline	99-09-2	65
3-Xylene	108-38-3	43
3,3'-Dichlorobenzidine	91-94-1	63
4-Methyl-2-pentyl Acetate	108-84-9	38
4-Nitroaniline	100-01-6	70
4,4'-Methylenebis(2-chloroaniline)	101-14-4	67
4,6-Dinitro-o-cresol	534-52-1	60
Acetaldehyde	75-07-0	26
Acetic Acid	64-19-7	23
Acetone	67-64-1	31
Acetone Cyanohydrin	75-86-5	107
Acetonitrile	75-05-8	33
Acetyl Acetone	123-54-6	43
Acetylene	74-86-2	16
Acrolein	107-02-8	30
Acrylamide	79-06-1	62
Acrylic acid	79-10-7	53
Acrylonitrile	107-13-1	33
Adiponitrile	111-69-3	59
Aldrin	309-00-2	75
Allyl Alcohol	107-18-6	47
Allyl Chloroformate	2937-50-0	35
Ammonia	7664-41-7	23
Aniline	62-53-3	52
Arsenic Trichloride	7784-34-1	35
Arsenic Trioxide	1327-53-3	77
Arsine	7784-42-1	17
Azinphosmethyl	86-50-0	68
Benzene	71-43-2	34
Benzidine	92-87-5	60
Benzyl Chloride	100-44-7	50
Benzyl Chloroformate	501-53-1	46
beta-Hexachlorocyclohexane	319-85-7	51
Bis(2-Chloroethyl) Ether	111-44-4	50
Bis(2-Chloroethyl)sulfide	505-60-2	60
Bis(2-Ethylhexyl) Phthalate	117-81-7	103
Bis(chloromethyl) Ether	542-88-1	33
Boron Trifluoride	7637-07-2	19
Bromine	7726-95-6	30
Bromoform	75-25-2	46
Butanenitrile	109-74-0	39
Cadmium, Elemental	7440-43-9	100

Carbon Dioxide	124-38-9	17
Carbon Disulfide	75-15-0	28
Carbon Monoxide	630-08-0	6
Carbon Tetrachloride	56-23-5	32
Carbonyl Sulfide	463-58-1	18
Chlordane	57-74-9	65
Chlorine	7782-50-5	18
Chlorine Trifluoride	7790-91-2	28
Chloroacetic Acid	79-11-8	61
Chloroacetyl Chloride	79-04-9	45
Chlorobenzene	108-90-7	41
Chlorodiethylaluminum	96-10-6	51
Chlorofenvinphos	470-90-6	62
Chloroform	67-66-3	31
Chloromethyl Methyl Ether	107-30-2	32
Chloropicrin	76-06-2	35
Chlorosulfonic Acid	7790-94-5	44
Chlorotrifluoromethane	75-72-9	16
Chlorpyrifos	2921-88-2	60
Cis-1,2-dichloroethylene	156-59-2	32
Cis-1,3-dichloropropene	10061-01-5	33
Cresol	1319-77-3	45
Crotonaldehyde	4170-30-3	37
Cumene Hydroperoxide	80-15-9	70
Cyanamide	420-04-2	50
Cyanogen	460-19-5	24
Cyanogen Bromide	506-68-3	46
Cyanogen Iodide	506-78-5	58
Cyanuric Fluoride	675-14-9	39
Cyclobutane	287-23-0	25
Cycloheptane	291-64-5	39
Cyclohexanone Peroxide	78-18-2	72
Cyclohexene	110-83-8	33
Cyclohexylamine	108-91-8	43
Cyclonite	121-82-4	84
Cyclopentane	287-92-3	29
Cyclopropane	75-19-4	17
DDD	72-54-8	89
DDT	50-29-3	84
delta-Hexachlorocyclohexane	319-86-8	51
Diallyl Phthalate	131-17-9	57
Diazinon	333-41-5	87
Diborane	19287-45-7	7
Dibromomethane	74-95-3	37
Dibutyl Phthalate	84-74-2	79
Dichlorodifluoromethane	75-71-8	20
Dichloromethane	75-09-2	29
Dichlorvos	62-73-7	68
Dicrotophos	141-66-2	55
Dicyclopentadiene	77-73-6	39
Dieldrin	60-57-1	83

Diethyl Ether	60-29-7	27
Diethyl Malonate	105-53-3	44
Diethyl Zinc	557-20-0	38
Diethylamine	109-89-7	31
Diglycidyl Ether	2238-07-5	44
Diisopropylamine	108-18-9	35
Dimethoate	60-51-5	95
Dimethyl Ether	115-10-6	19
Dimethyl Sulfate	77-78-1	47
Dimethyl Sulfoxide	67-68-5	52
Dimethylamine	124-40-3	25
Dipentylamine	2050-92-2	44
Diphosgene	503-38-8	37
Dipropyl Ether	111-43-3	36
Dipropylamine	142-84-7	44
Disulfoton	298-04-4	77
Endosulfan	115-29-7	68
Endrin	72-20-8	64
Epichlorohydrin	106-89-8	43
Ethane	74-84-0	5
Ethanol	64-17-5	42
Ethion	563-12-2	63
Ethyl Acetate	141-78-6	36
Ethyl Chloride	75-00-3	25
Ethyl Chloroacetate	105-39-5	40
Ethyl Mercaptan	75-08-1	27
Ethyl Methyl Ether	540-67-0	30
Ethyl Nitrate	625-58-1	37
Ethyl Nitrite	109-95-5	26
Ethylamine	75-04-7	29
Ethylbenzene	100-41-4	42
Ethylene	74-85-1	14
Ethylene Dibromide	106-93-4	42
Ethylene Glycol	107-21-1	66
Ethylene Glycol Diethyl Ether	629-14-1	43
Ethylene Glycol Mono-N-butyl Ether	111-76-2	57
Ethylene Oxide	75-21-8	25
Ethylenediamine	107-15-3	45
Ethyleneimine	151-56-4	30
Ethylphenyldichlorosilane	1125-27-5	51
Fluorine	7782-41-4	7
Formaldehyde	50-00-0	23
Furan	110-00-9	28
Furfuryl Alcohol	98-00-0	54
Glutaraldehyde	111-30-8	56
Glycolonitrile	107-16-4	51
Heptachlor	76-44-8	77
Hexachloro-1,3-butadiene	87-68-3	59
Hexachlorobenzene	118-74-1	74
Hexachlorocyclopentadiene	77-47-4	54
Hexachloroethane	67-72-1	54

Hexamethylene Diamine	124-09-4	51
Hydrazine	302-01-2	45
Hydrogen	1333-74-0	1
Hydrogen Bromide	10035-10-6	18
Hydrogen Chloride	7647-01-0	16
Hydrogen Cyanide	74-90-8	28
Hydrogen Fluoride	7664-39-3	25
Hydrogen Peroxide	7722-84-1	49
Hydrogen Sulfide	7783-06-4	14
Iodine, Elemental	7553-56-2	42
Iron Pentacarbonyl	13463-40-6	38
Isobutane	75-28-5	21
Isopentane	78-78-4	26
Isoprene	78-79-5	26
Isopropanol	67-63-0	45
Isopropylamine	75-31-0	28
Isopropylbenzene	98-82-8	45
Kepone	143-50-0	71
Lewisite	541-25-3	53
Lindane	58-89-9	51
Malathion	121-75-5	71
Mechlorethamine	51-75-2	55
Mesityl Oxide	141-79-7	43
Methacrolein	78-85-3	31
Methacrylic Acid	79-41-4	48
Methane	74-82-8	9
Methanesulfonyl Chloride	124-63-0	38
Methanol	67-56-1	37
Methoxychlor	72-43-5	67
Methyl Acrylate	96-33-3	38
Methyl Bromide	74-83-9	23
Methyl Chloride	74-87-3	19
Methyl Ethyl Ketone	78-93-3	35
Methyl Formate	107-31-3	28
Methyl Isobutyl Ketone	108-10-1	43
Methyl Isocyanate	624-83-9	27
Methyl Isothiocyanate	556-61-6	37
Methyl Mercaptan	74-93-1	24
Methyl Methacrylate	80-62-6	36
Methyl N-Butyrate	623-42-7	40
Methyl Parathion	298-00-0	89
Methyl Salicylate	119-36-8	48
Methyl Vinyl Ketone	78-94-4	33
Methylacrylonitrile	126-98-7	37
Methylamine	74-89-5	23
Methylhydrazine	60-34-4	36
Methylpyridines	1333-41-1	35
Methyltrichlorosilane	75-79-6	31
Morpholine	110-91-8	45
n-Butane	106-97-8	22
n-Butyl Acetate	123-86-4	44

n-Butyl Acrylate	141-32-2	45
n-Butyl Alcohol	71-36-3	52
n-Butyl Isocyanate	111-36-4	35
n-Butylamine	109-73-9	36
n-Butyric Acid	107-92-6	40
n-Dodecane	112-40-3	43
n-Ethylaniline	103-69-5	58
n-Heptane	142-82-5	37
n-Hexane	110-54-3	32
n-Nitrosodi-n-propylamine	621-64-7	42
n-Nitrosodimethylamine	62-75-9	37
n-Nitrosodiphenylamine	86-30-6	59
n-Nonane	111-84-2	47
n-Octane	111-65-9	41
n-Pentane	109-66-0	26
n-Propylbenzene	103-65-1	46
n-Tridecane	629-50-5	45
n-Undecane	1120-21-4	57
N,N-Dimethylformamide	68-12-2	48
Naphthalene	91-20-3	53
Nickel Carbonyl	13463-39-3	27
Nitric Acid	7697-37-2	39
Nitrobenzene	98-95-3	55
Nitrogen tetroxide	10544-72-6	38
Nitrogen, Elemental	7727-37-9	6
Nitroglycerin	55-63-0	105
Nitromethane	75-52-5	38
Nitrous Oxide	10024-97-2	17
o-Cresol	95-48-7	45
Oleic Acid	112-80-1	67
p-Cresol	106-44-5	62
Parathion	56-38-2	60
Pentachlorophenol	87-86-5	69
Peracetic acid	79-21-0	44
Phenol	108-95-2	58
Phenyl chloroformate	1885-14-9	42
Phenyl Isocyanate	103-71-9	40
Phenylacetonitrile	140-29-4	47
Phenylhydrazine	100-63-0	59
Phorate	298-02-2	51
Phosgene	75-44-5	25
Phosphine	7803-51-2	186
Phosphorus Oxychloride	10025-87-3	34
Phosphorus Trichloride	7719-12-2	31
Phosphorus, Elemental	7723-14-0	17
Phthalic Anhydride	85-44-9	65
Phthaloyl Chloride	88-95-9	52
Picric Acid	88-89-1	106
Pinacolyl Alcohol	464-07-3	54
Piperidine	110-89-4	38
Propadiene	463-49-0	23

Propane	74-98-6	15
Propargyl Alcohol	107-19-7	42
Propionaldehyde	123-38-6	30
Propionic Acid	79-09-4	55
Propionic Anhydride	123-62-6	48
Propionitrile	107-12-0	36
Propyl Mercaptan	107-03-9	32
Propylamine	107-10-8	31
Propylene	115-07-1	19
Pyridine	110-86-1	40
Pyrrolidine	123-75-1	38
Radon, Radioactive	10043-92-2	0
Salicylaldehyde	90-02-8	45
Sarin	107-44-8	37
sec-Butyl Acetate	105-46-4	35
sec-Butyl Alcohol	78-92-2	50
Selenium, Elemental	7782-49-2	60
Silicon Tetrafluoride	7783-61-1	17
Sodium Hydroxide	1310-73-2	175
Soman	96-64-0	42
Styrene	100-42-5	44
Sulfur Dioxide	7446-09-5	25
Sulfur Hexafluoride	2551-62-4	10
Sulfur Trioxide	7446-11-9	43
Sulfuric Acid	7664-93-9	63
Sulfuryl Chloride	7791-25-5	31
Tabun	77-81-6	48
Terpinolene	586-62-9	51
tert-Butyl Hydroperoxide	75-91-2	42
tert-Butylamine	75-64-9	30
Tetrachloroethylene	127-18-4	40
Tetraethyl Pyrophosphate	107-49-3	48
Tetrafluoroethylene	116-14-3	17
Tetrahydrofuran	109-99-9	32
Tetrahydrothiophene	110-01-0	39
Tetramethyl Lead	75-74-1	36
Tetranitromethane	509-14-8	47
Thiodiglycol	111-48-8	28
Thionyl Chloride	7719-09-7	32
Thiophene	110-02-1	35
Thiophenol	108-98-5	40
Titanium Tetrachloride	7550-45-0	38
Toluene	108-88-3	38
Toluene Diisocyanate	26471-62-5	49
Trans-1,2-dichloroethylene	156-60-5	30
Trans-1,3-dichloropropene	10061-02-6	33
Triallylamine	102-70-5	39
Tributylamine	102-82-9	45
Trichloroacetyl Chloride	76-02-8	36
Trichloroethylene	79-01-6	35
Trichlorosilane	10025-78-2	25

Triethyl Phosphite	122-52-1	38
Triethylamine	121-44-8	35
Trifluoromethane	75-46-7	17
Triisobutylaluminum	100-99-2	38
Trimethyl Borate	121-43-7	34
Trimethyl Phosphite	121-45-9	43
Trimethylamine	75-50-3	22
Trimethylchlorosilane	75-77-4	30
Tripropylamine	102-69-2	46
Tris(2-Chloroethyl)amine	555-77-1	65
Turpentine	8006-64-2	50
Uranium, Elemental	7440-61-1	447
Vanadium, Elemental	7440-62-2	459
Vinyl Acetate	108-05-4	34
Vinyl Bromide	593-60-2	23
Vinyl Chloride	75-01-4	23
Vinyl Fluoride	75-02-5	17
Vinyl Methyl Ether	107-25-5	23
VX	50782-69-9	101
Xylenes	1330-20-7	36