



Defence and Security  
Accelerator



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# **Saving their skin (and other organs): military and police personal armour**

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# Scope

- What is personal armour?
- Why wear armour – the threat?
- What anatomical structures do we need to protect?
- What materials do we use?
- How do those materials work?
- Challenges for the future?

# What is personal armour?

- body armour (waistcoat or tabard style, often modular)
- helmets
- pelvic protection
- face and eye protection (visors, glasses, goggles)
- Explosive Ordnance Disposal suits
- ballistic shields and blankets
- public order

# Why wear personal armour?

- to save lives
- to prevent/minimise life changing injuries
- threat is role specific



Carr et al., 2015

## Threat - military

	<b>bullets</b>	<b>fragments</b>	<b>other</b>
WWI	39	61	
WWII	10	85	5
Korea	7	92	1
Vietnam	52	44	4
Borneo	90	9	1
NI	56	23	21
Israel 1982	12	53	35
Falklands	32	56	12
Gulf 1991*	20	80	

Ryan et al., 1991

## Threat - military



fragments from a mortar



various types of ammunition

# Surface wound mapping - Korean War

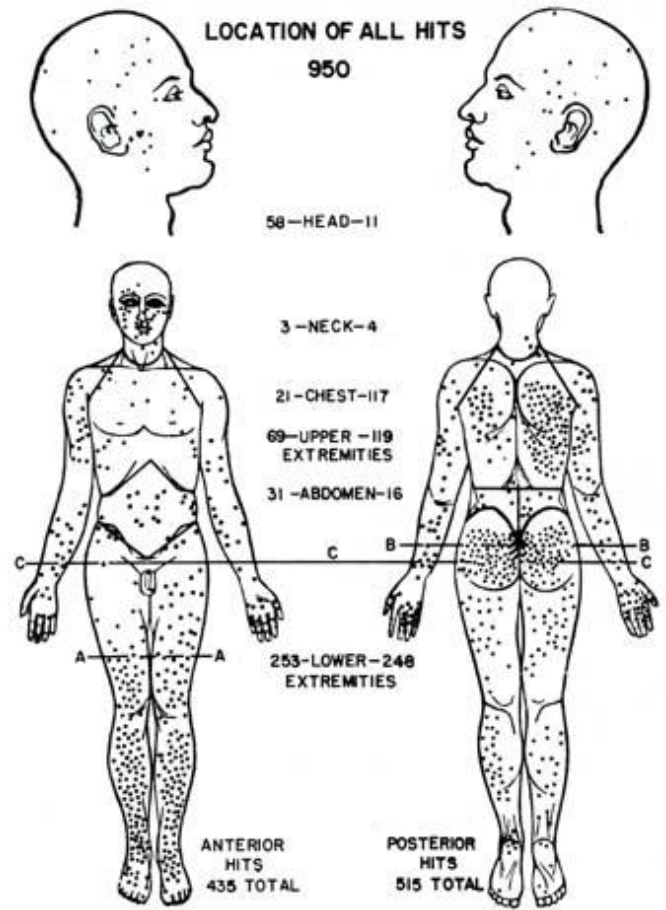


FIGURE 339.—Location of wounds in 286 Turkish soldiers wounded in action.

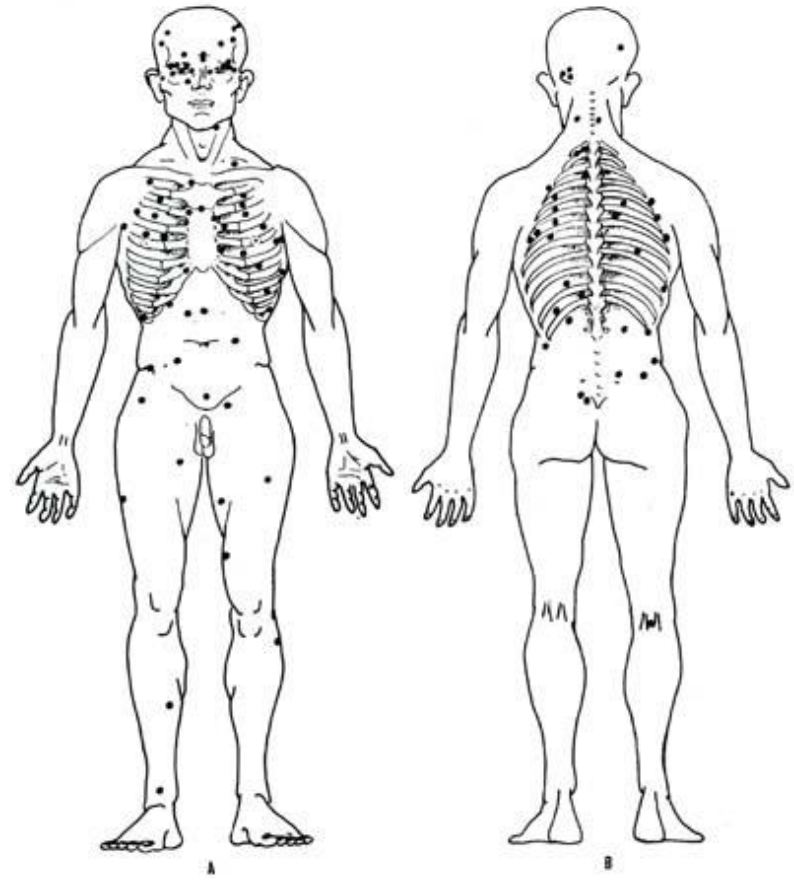
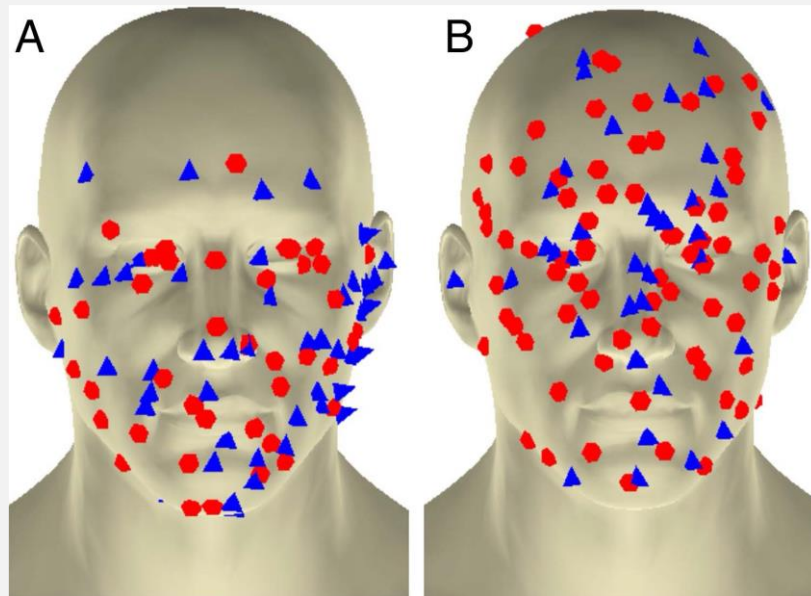


FIGURE 187.—Entrance sites of lethal wounds in 104 autopsied casualties.  
A. Anterior view. B. Posterior view.

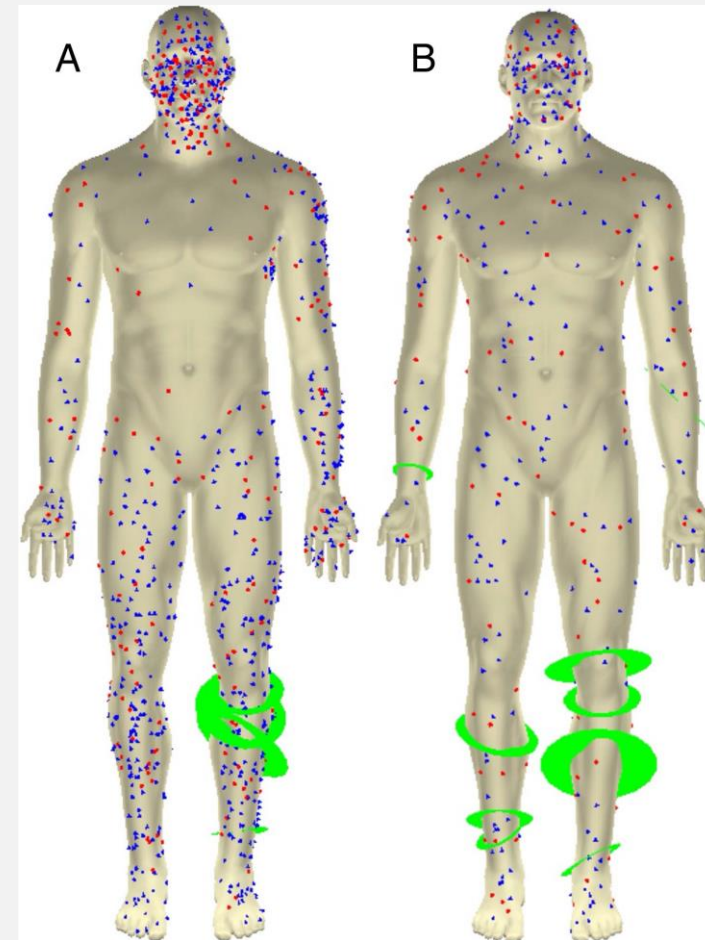


# Surface wound mapping - Afghanistan



helmet worn

no helmet worn



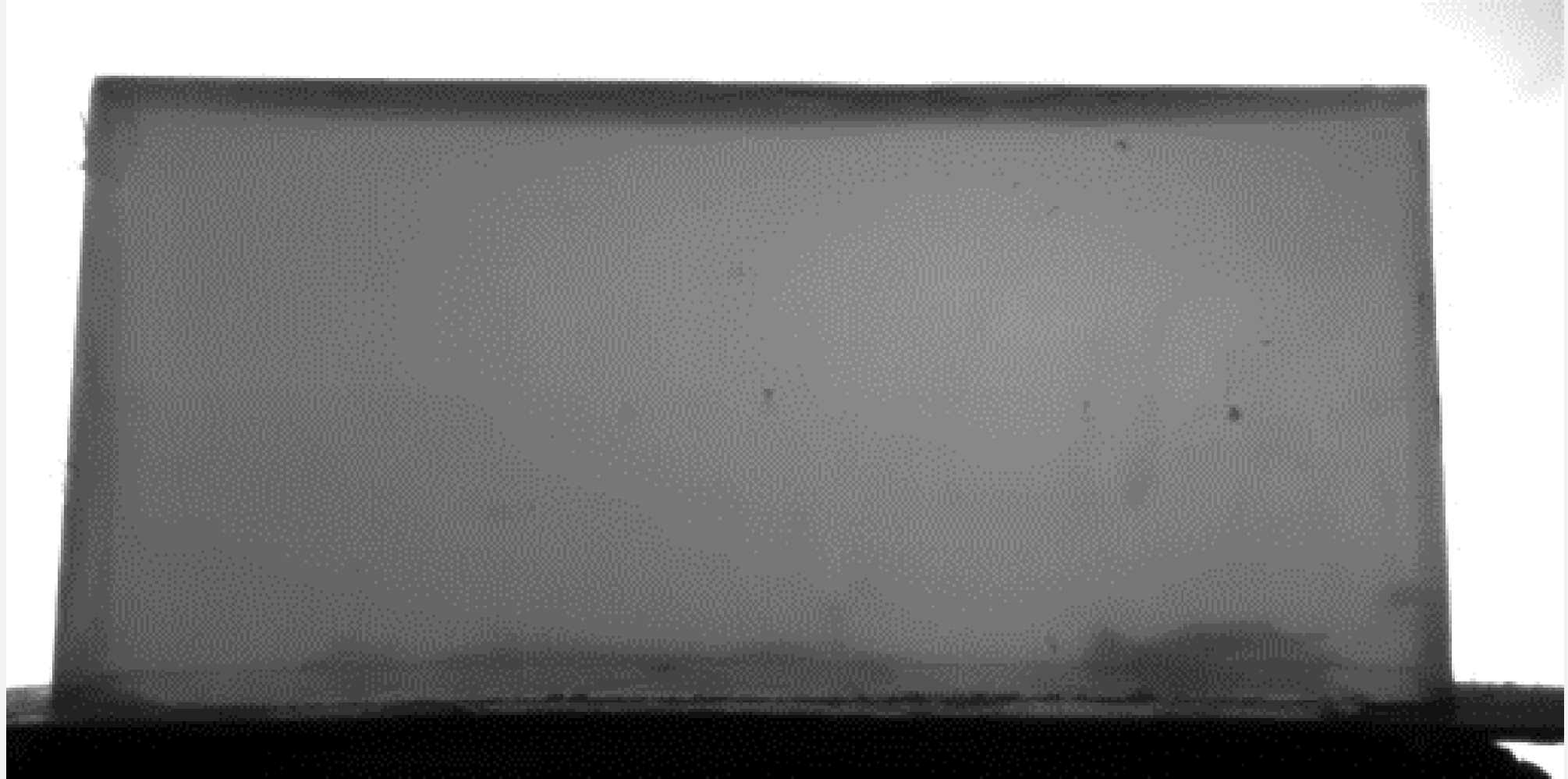
body armour worn

no body armour worn

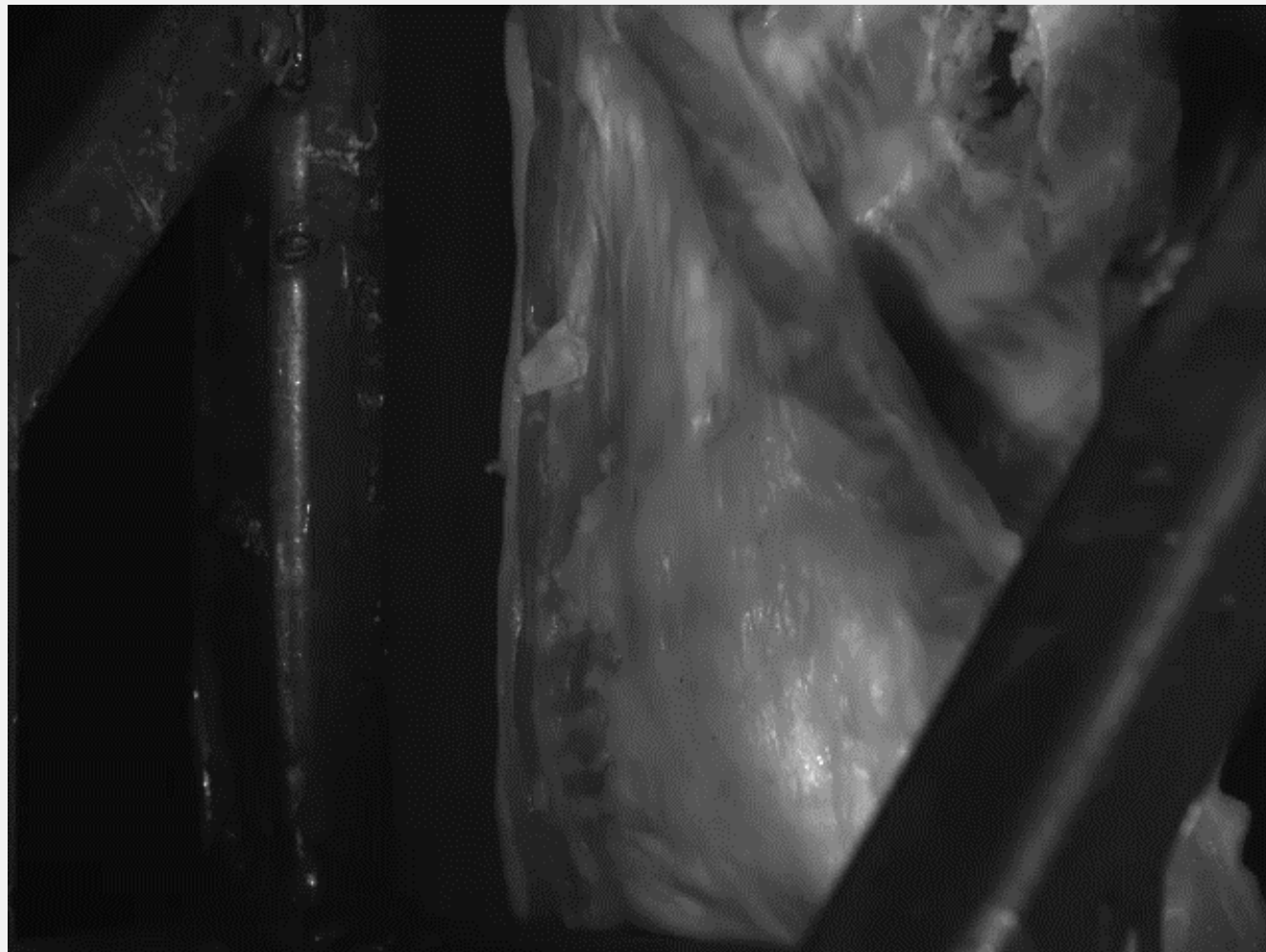
**5.5 mm diameter steel ball bearing 750 m/s (Mahoney, 2016)**



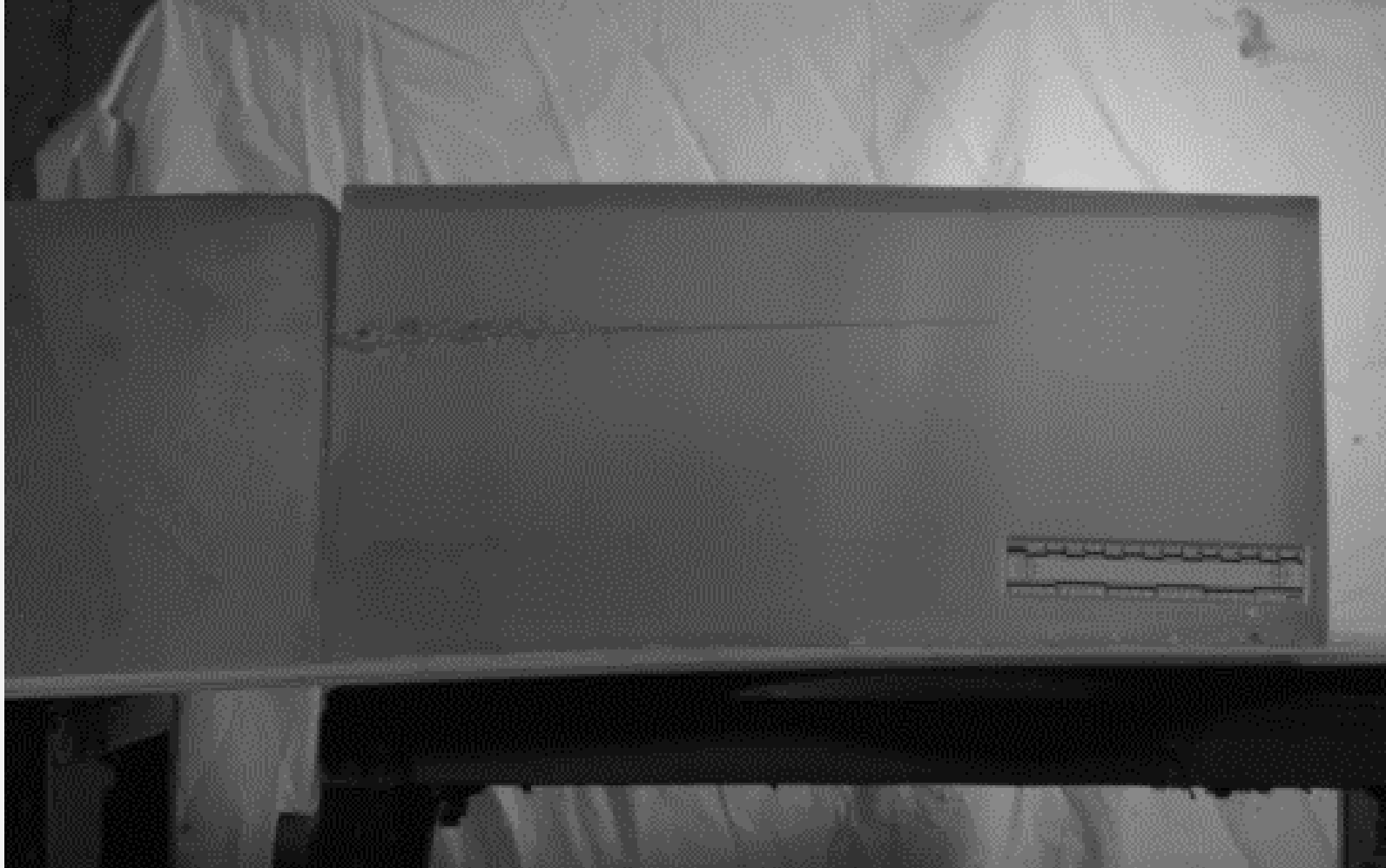
**9mm FMJ bullet, 425 m/s (Mabbott, 2015)**



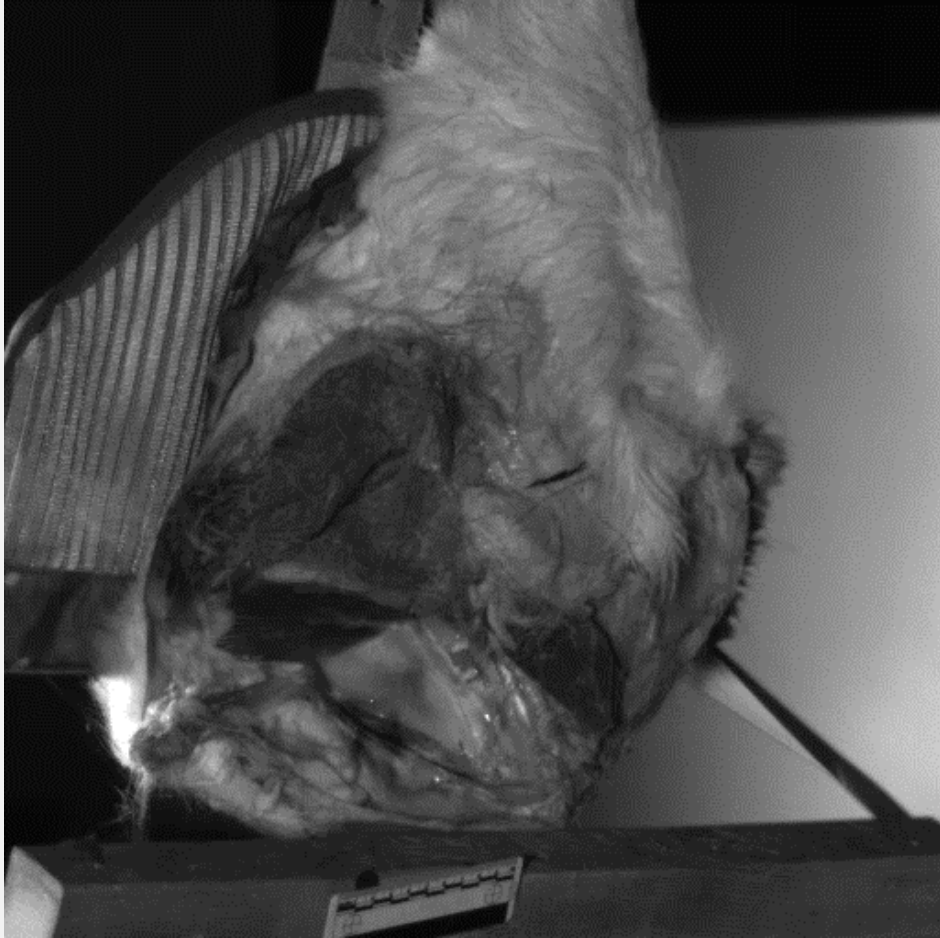
## 9mm FMJ, swine rib (Carr et al., 2015)



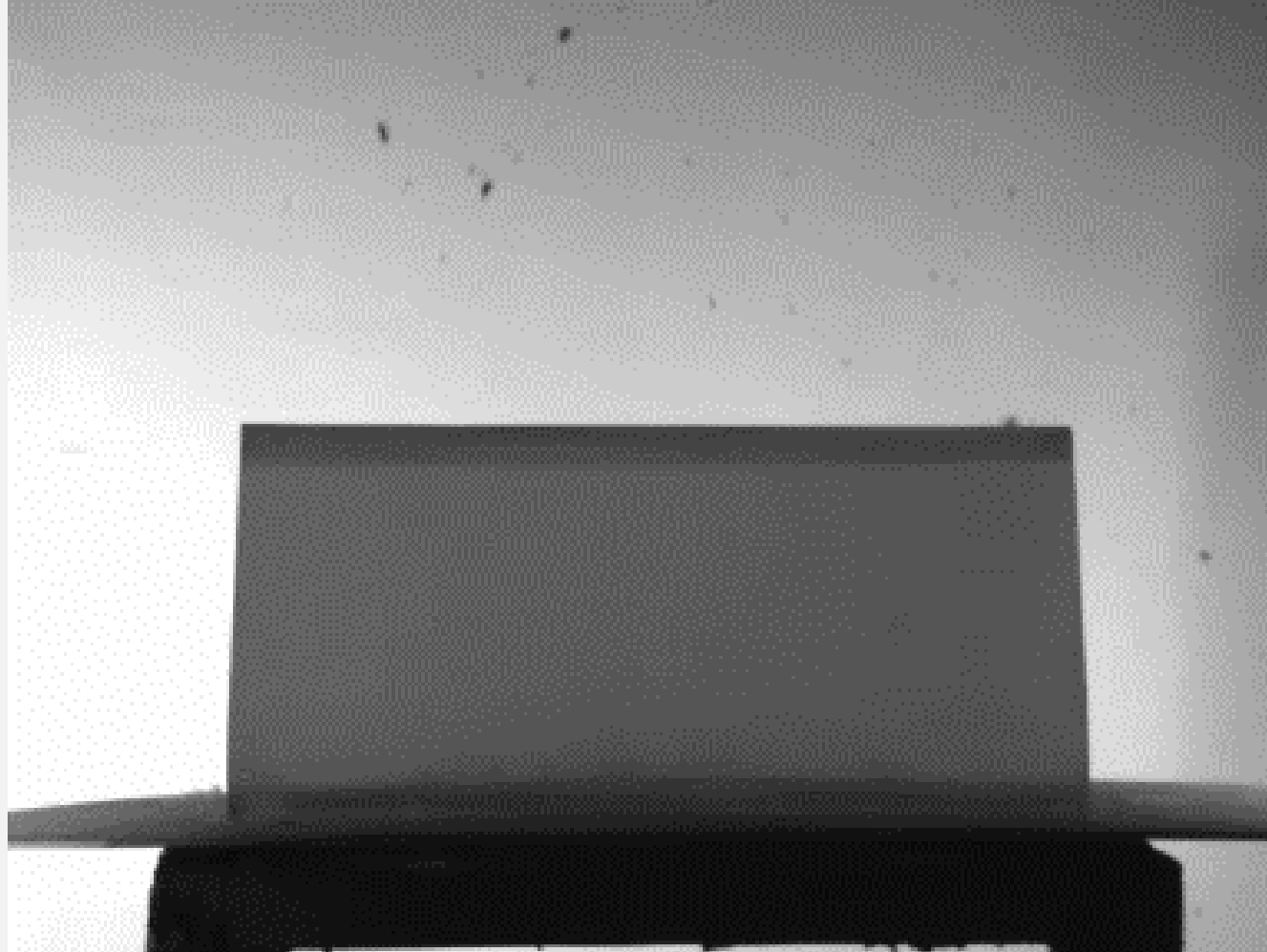
# 7.62mm bullet, 720 m/s (Mahoney, 2016)



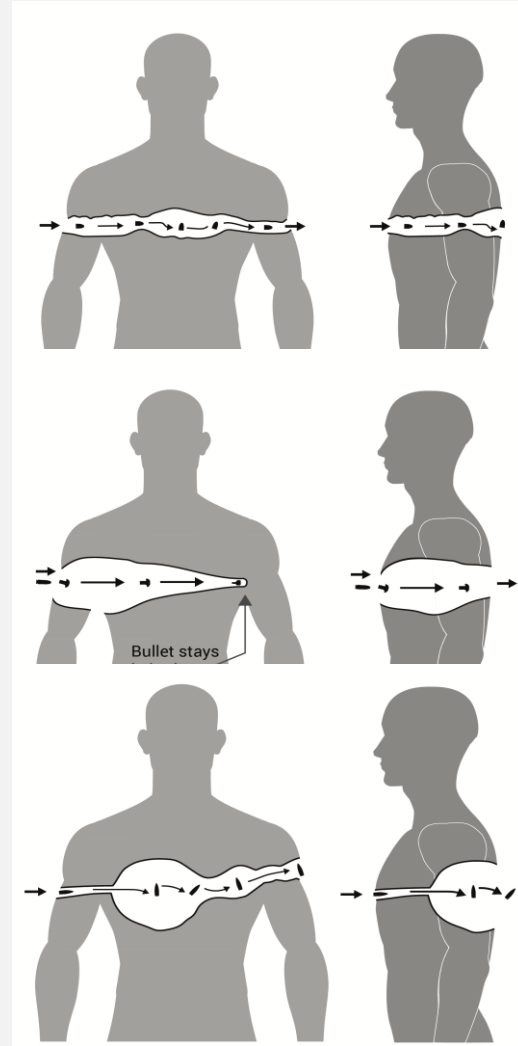
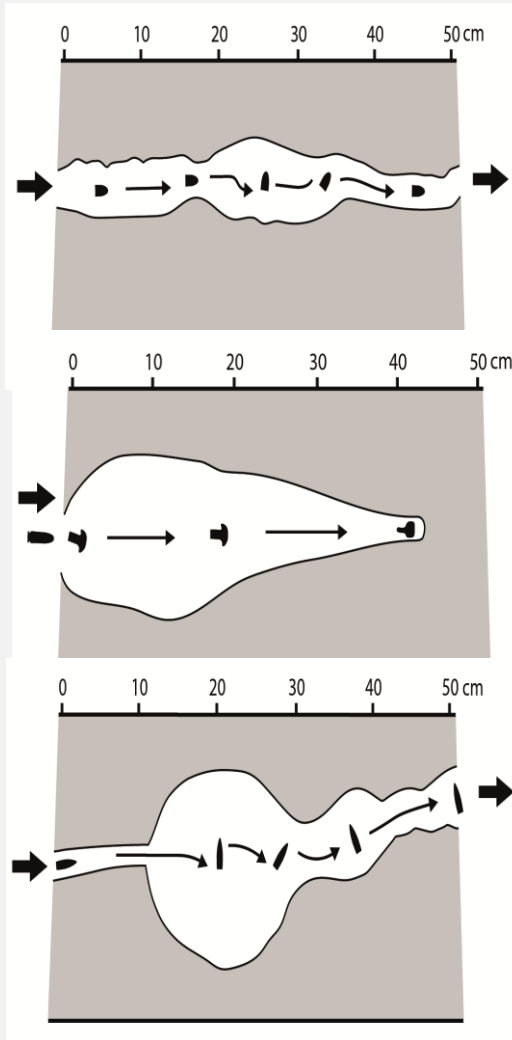
**7.62mm, fallow deer limb (Stevenson, 2017)**



# 5.56mm bullet 925 m/s (Carr, 2017)



# Gelly vs human



Carr et al., 2018



## Threat – police / blue-light

- sharp-weapons not just knives
- low-velocity pistol ammunition
- shotguns
- high-velocity rifle ammunition



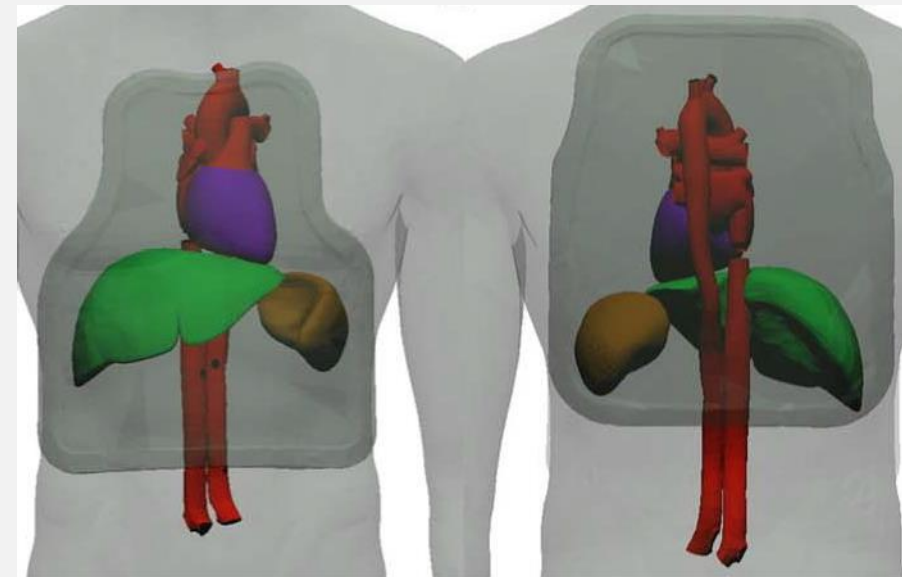
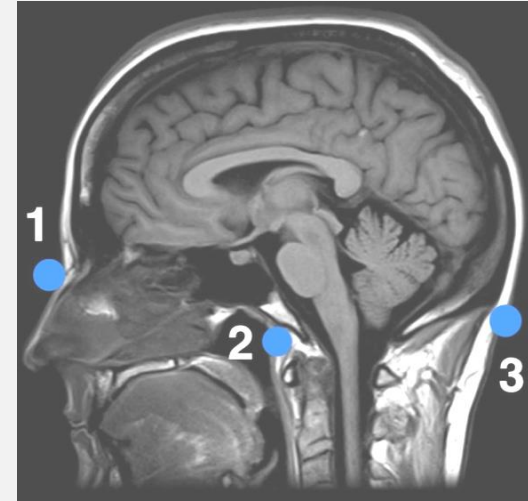
# Knife crime (Cowper et al, 2017)



## Area of coverage

**essential protection** brain and brain stem; heart, great vessels, liver and spleen

**desirable protection** lungs, kidneys, trachea and main bronchi, spinal cord, intestines



Breeze et al., 2013

Breeze et al., 2015

# Body armour construction

- protective pack
  - fabric / other materials
  - threat dependant
- light- and water-resistant cover
- carrier



Lewis et al., 2017

# Helmet construction

- composite shell
- foam liner
- height adjustment
- comfort padding
- chinstrap
- cover

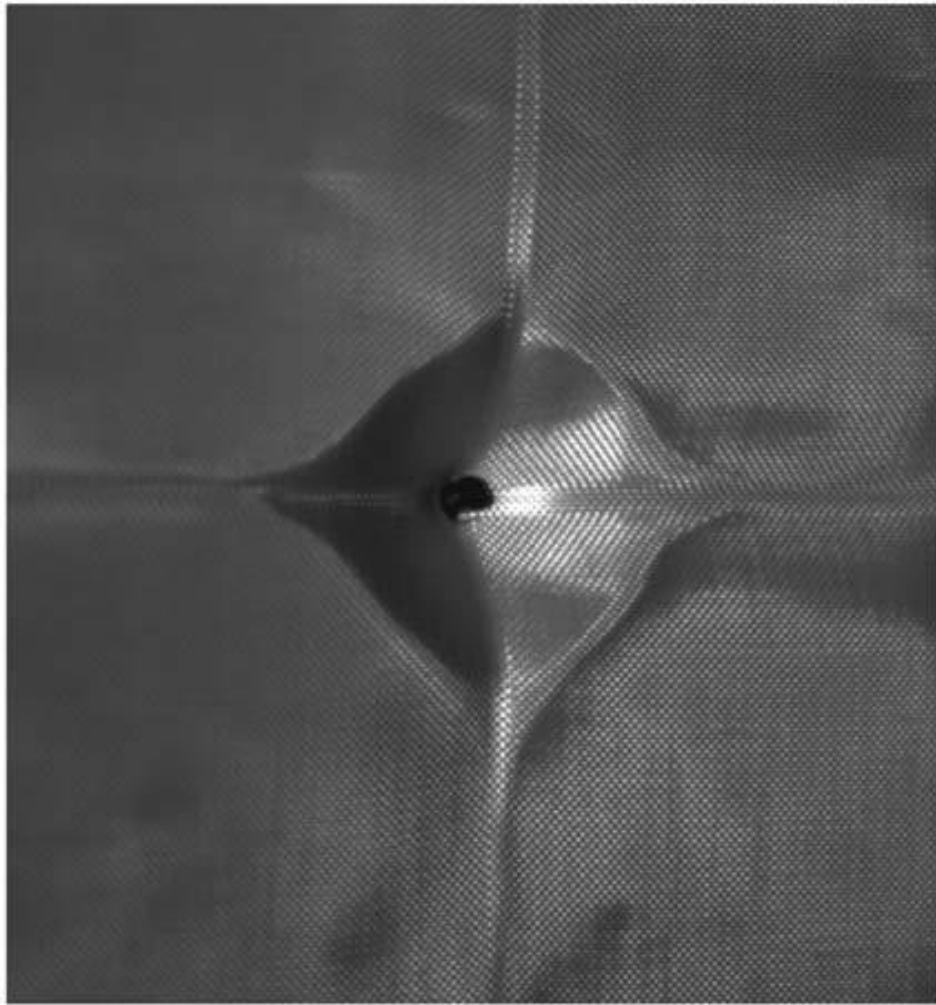


# What materials?

- fragmentation and low-velocity pistol ammunition
  - fabrics – high strength fibres
  - para-aramid and UHMWPE
- high-velocity rifle protection
  - ceramic faced / composite backed plate
  - composite plate
- sharp-weapons
  - over-lapping plates or chainmail
  - resin coated fabrics (usually para-aramid)

# Stopping fragments and pistol bullets

- non-deformable (metallic fragments) vs. deformable (pistol)
- impact energy dissipated along yarns
- transverse deformation
  - related to velocity of projectile
- pyramidal deformation
- fibre, yarn failure



Sakaguchi et al, 2012

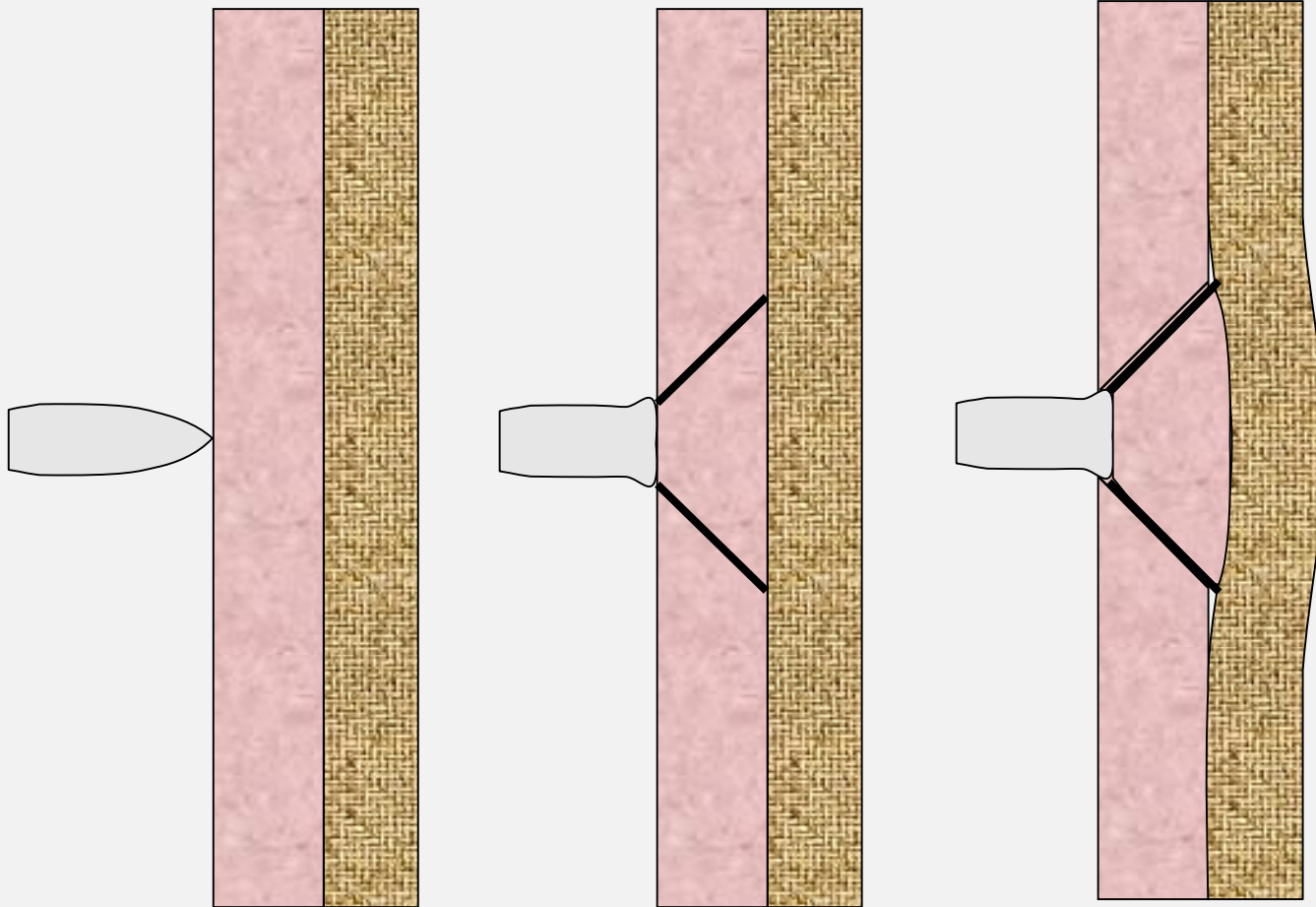


## Failure mechanisms: sharp-weapons

- rigid plates (overlapping): metallic / composite
- coated / laminated fabric:
- chainmail
- key for protection is to:
  - turn the tip over ↓ KED
  - capture the sharp-weapon tip



# Failure mechanisms: rifle bullet protection



# Use of ceramics

Material	density (g/cc)	hardness (Hv)
alumina	3.8	1600
silicon carbide	3.2	2800
boron carbide	2.5	3000
steel	7.75	500



## Behind armour blunt trauma (BABT)

“... the non-penetrating injury resulting from the rapid deformation of armours covering the body.”  
(Cannon, 2001)

Ranger Ryan Boyd left with a bruise after being shot

<http://www.bbc.co.uk/newsbeat/11641486>  
[01/03/2014]



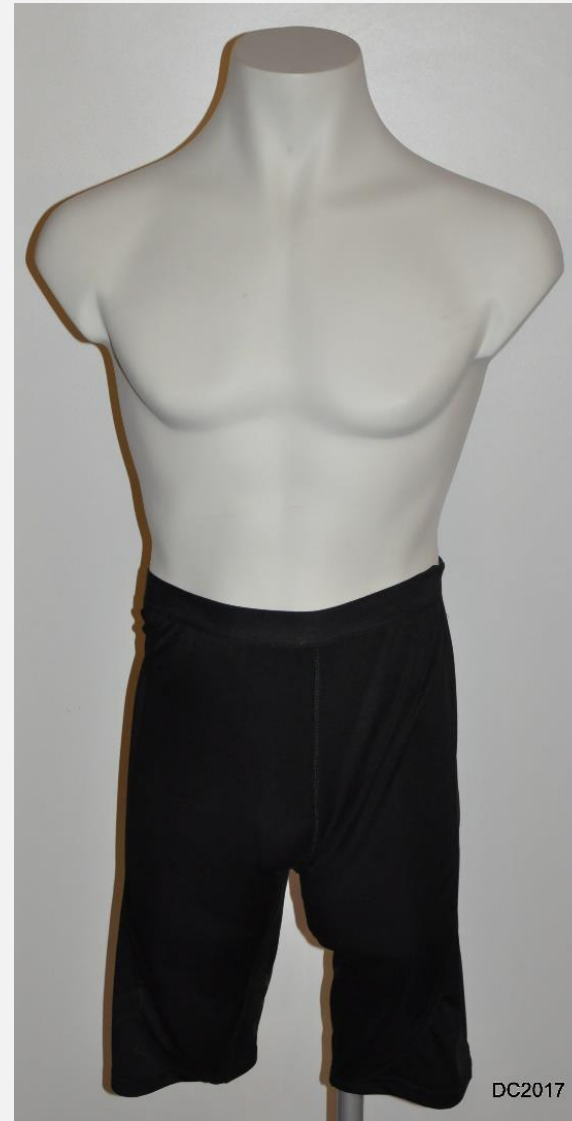
## Typical BABT injuries

- skin contusion, laceration
- rib fracture
- contusions to lungs, kidneys, spleen and (very rarely) the heart

‘From experience on the combat field there is very little evidence of its existence, apart from ... minor breathlessness or bruising.’ NATO Specialist Team on Body Armour (2002).

## Other items

- pelvic – fragmentation
- eye
- fire-resistant overalls



# Challenges

- effect on human performance
- body armour is heavy, restrictive, ↑ thermophysiological burden
- major issues: high thermal resistance, low permeability, area of coverage
- mass is a less critical factor - contributes towards fatigue
- cooling strategies can be useful
  - increased mass and bulk
  - recharging or a power source
- reduce bulk and mass – same protection

# Summary

- Personal armour is threat and role specific.
- For military armour, protection is primarily from fragmentation and high-velocity rifle ammunition.
- For police armour, protection is primarily from sharp-weapons and low-velocity pistol ammunition.
- Personal armour (excluding EOD suits) does not provide protection from blast injuries.



# Acknowledgements and questions

- MIS/ICorr for the invitation
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