

What's new in stunning technologies?

Alison Small

8 August 2019

New???

Early man

- Humans emerged over 200,000 years ago
  - Hunter-gathering
- Farming emerged around 10,000 years ago
  - Closer relationship with animals

- Good reasons for humane slaughter
  - Fast
  - Safe
- Tools?
  - Clubs, spears, arrows
  - Mechanical methods

Before 1900s

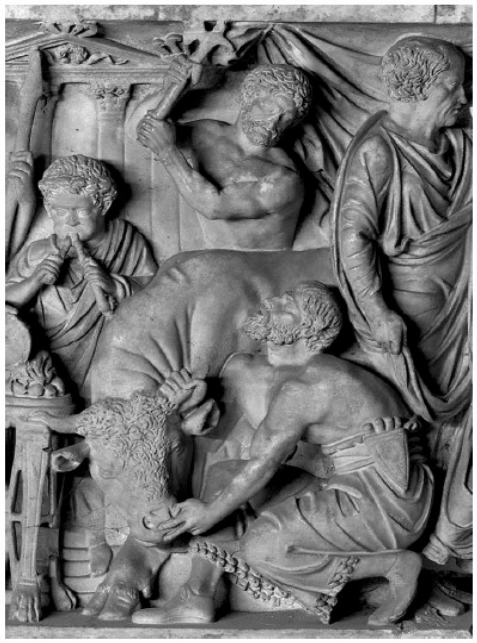


FIG. 5. Relief from sarcophagus in Museo del Palazzo Ducale, Mantua, of sacrifice scene showing *popa* with upraised axe prior to striking at animal's neck. (*Photo: Scala/Ministero per i Beni e le Attività culturali/Art Resource, NY*)

Source: Aldrete 2014, Journal of Roman Studies

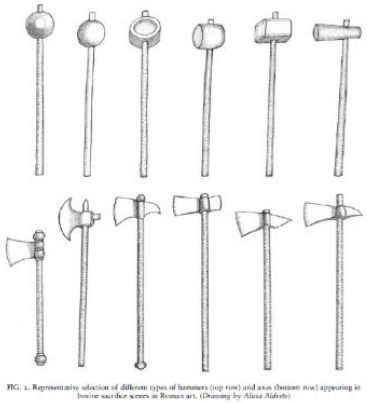
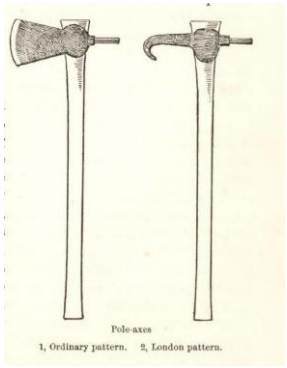
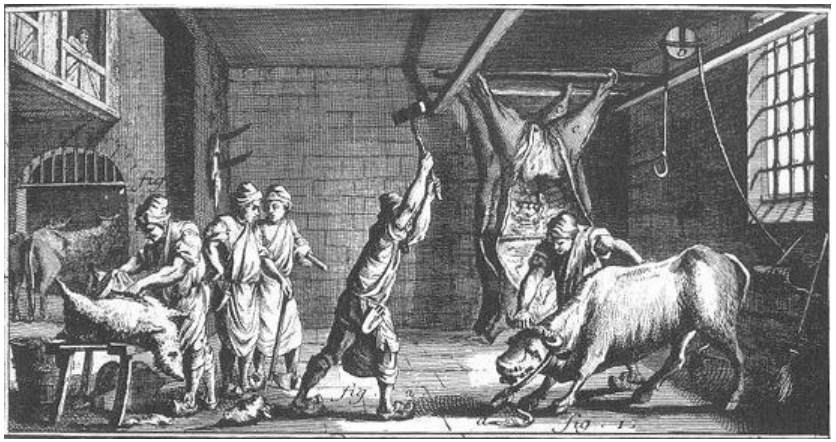


FIG. 1. Representative selection of different types of hammers (top row) and axes (bottom row) appearing in bovine sacrifice scenes in Roman art. (Drawing by Alicia Aldrete)



Source: Food Inspection (McEwen, 1922)



Source: Diderots Encyclopaedia of 18th Century Butchers' Tools: www.livinghistory.co.uk

1920s

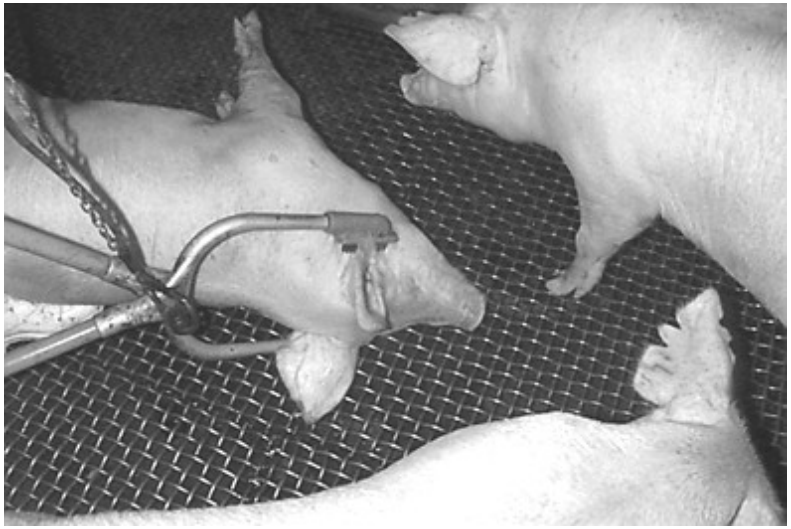
- Development of the captive bolt

Source: Food Inspection (McEwen, 1922)

Source: CSIRO

1920s to 1930s

- Emergence of electrical stunning
  - *Grand mal* epileptiform fit



Source: CSIRO

Species	Minimum current
Pigs	1.3 A
Sheep and goats	1.0 A
Lambs and kids	0.6 A
Calves	1.0 A
Cattle	1.2 A

1930s

- Emergence of gas stunning/killing (controlled atmosphere)
  - Pigs and Poultry
  - CO_2

Lots of recent activity 1990s to date

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ELSEVIER

Review

Broiler stunning methods and their effects on welfare, rigor mortis, and meat quality

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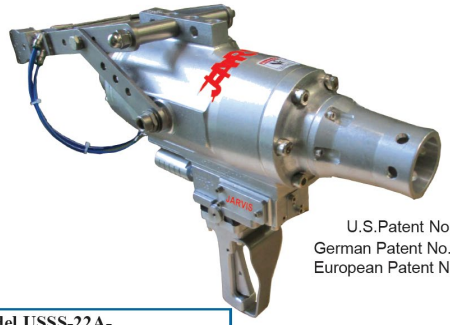
This presentation

- *Is* about:
  - Published findings in the past 5 years
  - Stunning technologies and equipment
    - Refinements to existing methods
    - Understanding more deeply factors affecting efficacy
    - Emerging technologies
- Is *not* about
  - Policy and opinion
  - The unstunned slaughter debate
  - Physiology and behaviour

Mechanical stunning

Recent mechanical stun developments

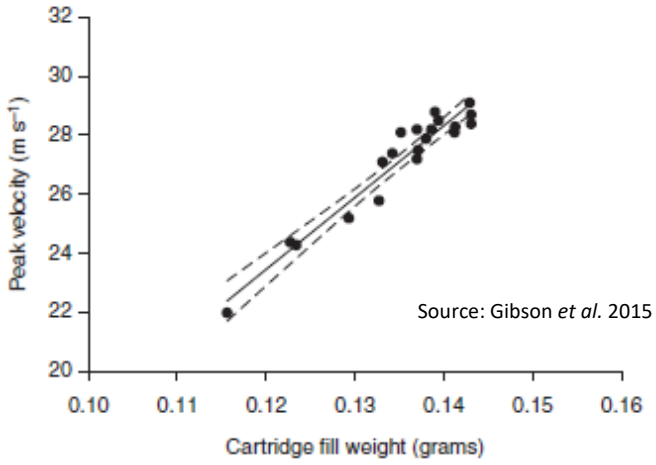
- Improved captive bolt instruments
  - More efficient cartridge-driven instruments
  - Compressed-air driven captive bolt instruments
- Factors affecting performance
  - Bench testing of 6 captive bolt pistols (Gibson et al. 2015)
  - Cash special (.22) reached 88.8°C after 2hr firing at 4 shots/minute
  - Extended periods of repeat firing reduces performance



U.S.Patent No. 6,135,871
German Patent No.DBP603 48 402.6
European Patent No. EP1613164

The Jarvis Model USSS-22A-pneumatically operated high speed, non-penetrating stunner for cattle and veal.

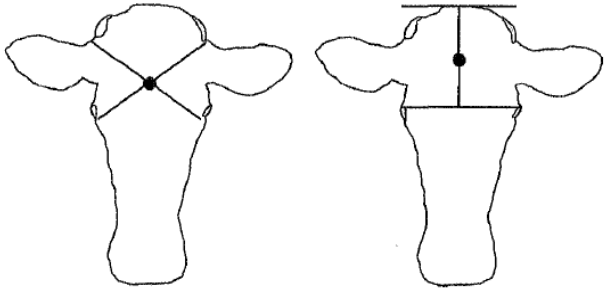
Source: www.jarvisanz.com.au



Source: Gibson *et al.* 2015

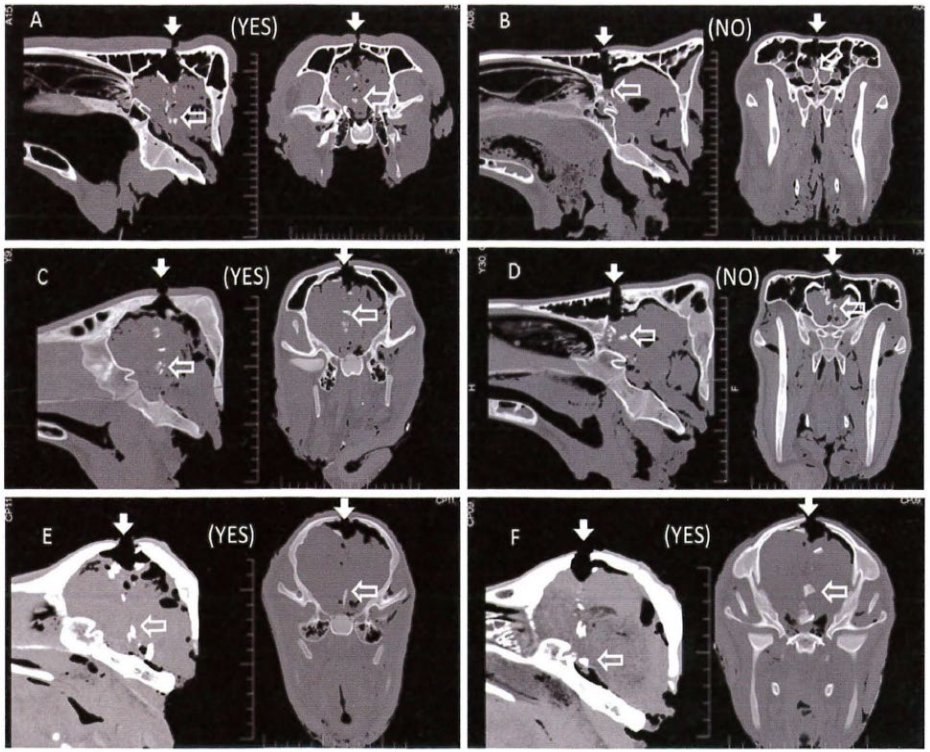
Optimal positioning

A slightly higher application point has greater chance of damaging the brainstem



LOW shot position (left) denoted as the intersection of two lines drawn from the medial canthus of each eye to the opposite horn or top of the opposite ear. HIGH shot position (right) denoted as a point on midline halfway between the top of the poll and a line drawn between the lateral canthus of each eye.

HIGH LOW



> 24 months

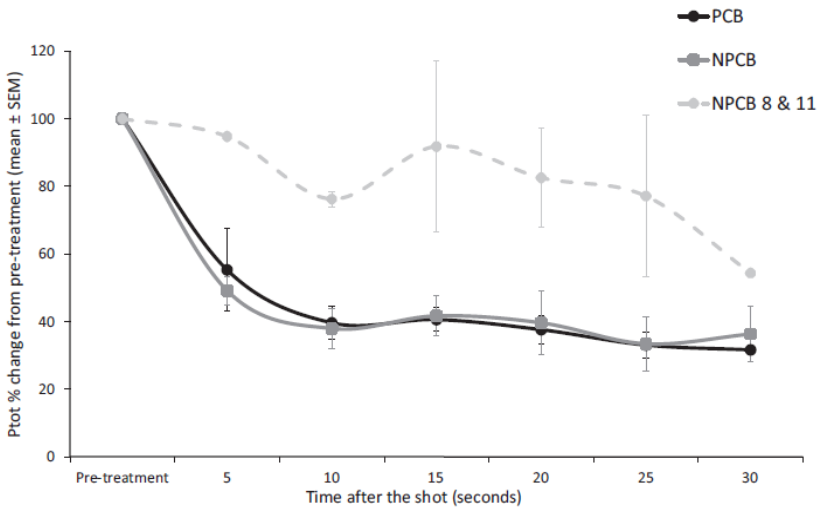
6 – 24 months

< 1 month

- Gilliam *et al.* 2016

Comparison of penetrative, percussive and non-stun

- Gibson et al 2019
  - 30 mo Bulls
  - Penetrative stunned 20/20
  - Percussive stunned 8/11



- Zulkifli et al 2014
  - EEG suppression most pronounced in penetrative stun
  - Blood volume collected greatest with thoracic stick

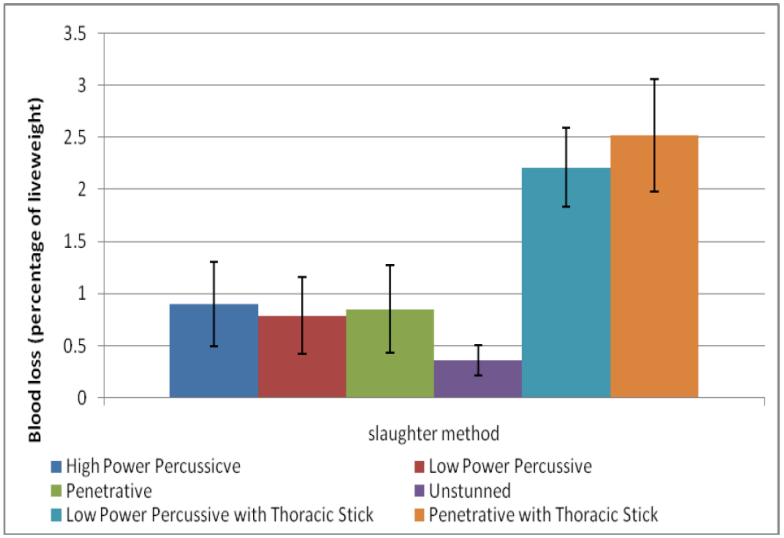


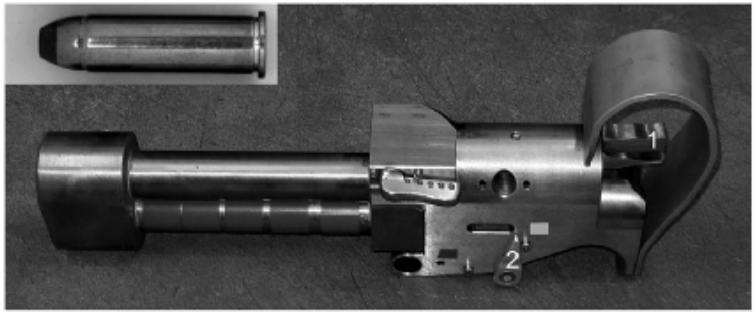
Figure 2: Blood weight collected at sticking (as a percentage of liveweight).

Non-penetrating mechanical stun

- Very important in Australian industry – halal acceptance
- EU – only permitted for animals under 10kg
  - European in-plant surveys showing efficacy rates as low as 64% in grown livestock
  - Australian plants target 95-98% as a KPI
  - Why the difference?

Mechanical stunning of buffalo

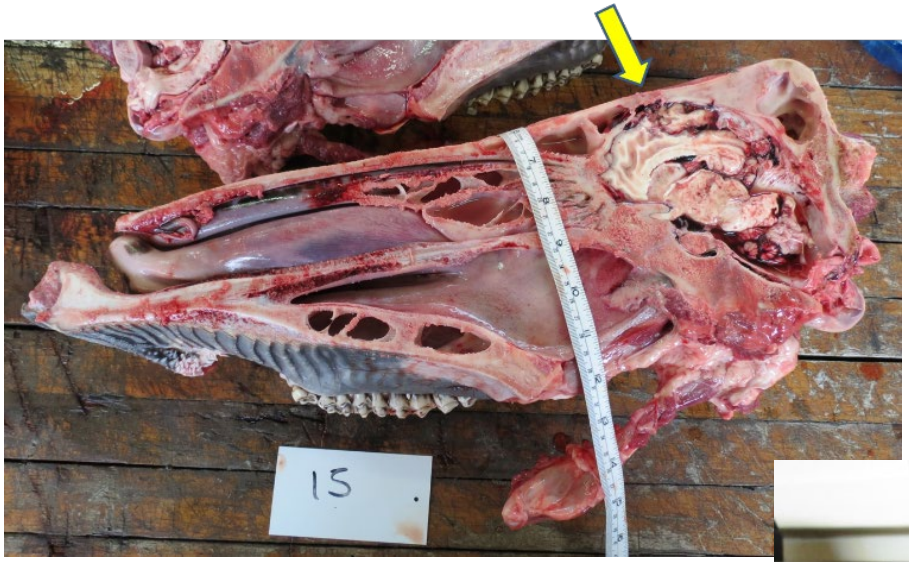
- High power ballistic is effective at frontal position
  - New .357 Magnum hollow point device
  - Europe

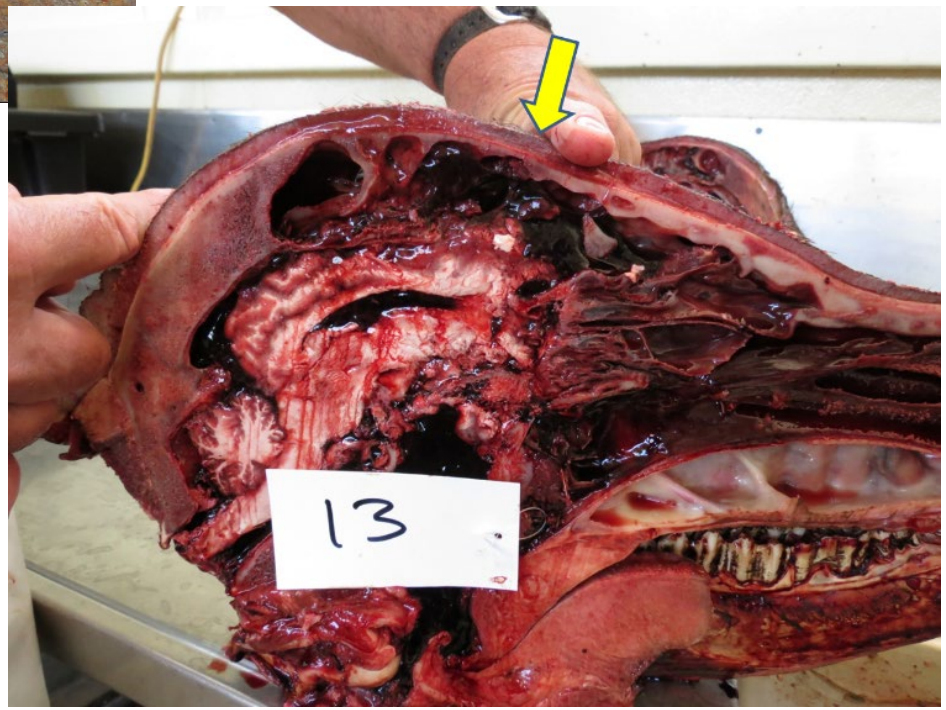


Source: Meichtry *et al.* 2018

- Occipital/poll position for captive bolt
- Challenge:
  - Halal compliance
  - SE Asia

Source: CSIRO





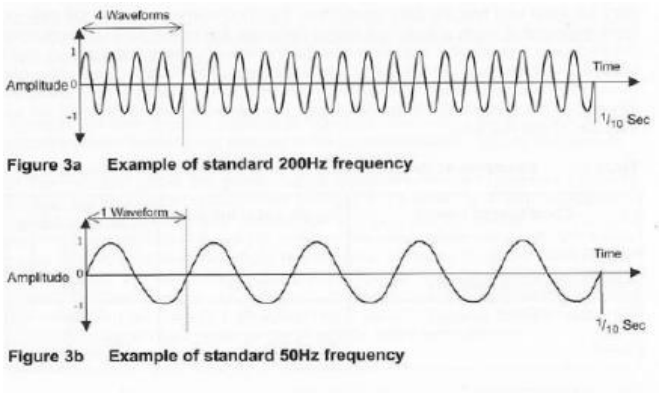
Source: AgriFutures Australia Ltd / CSIRO project. “Developing Appropriate Stunning Methods for Halal Slaughter of Water Buffalo”

Electrical stunning

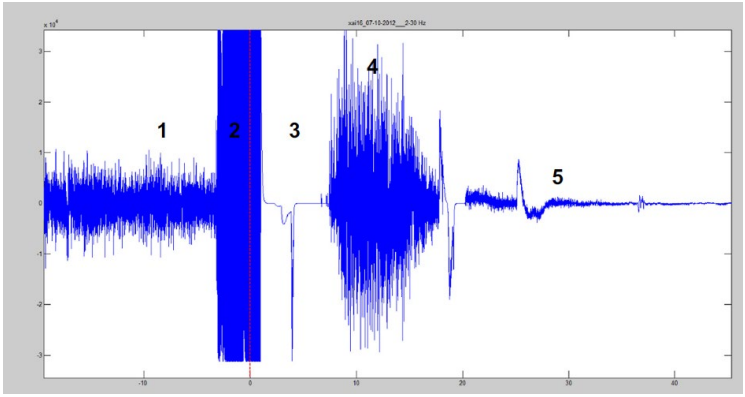
More recent electrical stun developments

- Improved electrical stun methods
  - High frequency current
  - Different current waveforms

- Appropriate currents for light lambs (<16 kg)
  - 0.3, 0.5 and 0.7 A induce effective stunning similar to 1.0 A in lambs and kid goats (Llonch *et al.* 2015)
  - Aim – reduction in blood splash



Source: Humane Slaughter Association



Source: Llonch *et al.* 2015

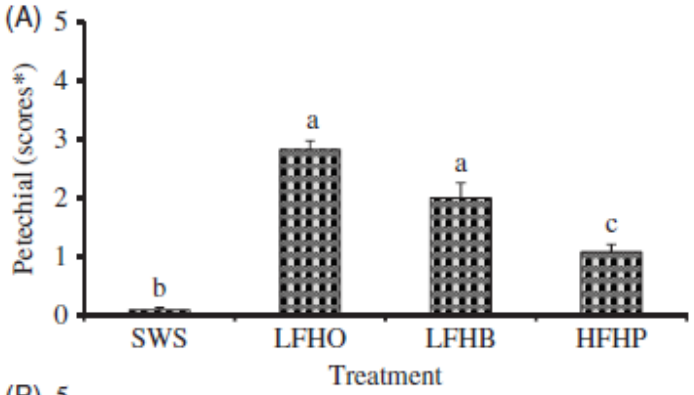
High frequency electrical stunning

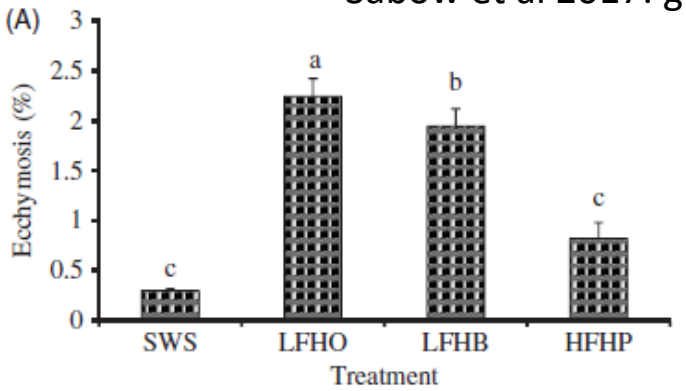
- Reduction in blood splash
- Reduction in clonic activity
  - Short pulse durations (100 µs) of 2000 Hz can reduce post-stun movement while minimising impact on pH decline
- Head-to-back HFES
  - Effective stun
  - Maintained cardiac function
  - Reduced clonic activity
  - Potential halal acceptability

(refs: Simmons *et al.* 2006; Farouk 2013; Sabow *et al.* 2017; Sabow *et al.* 2018)

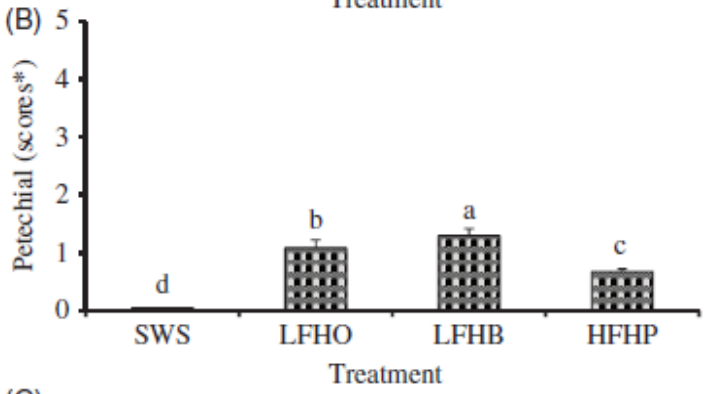
Sabow et al 2017: goats

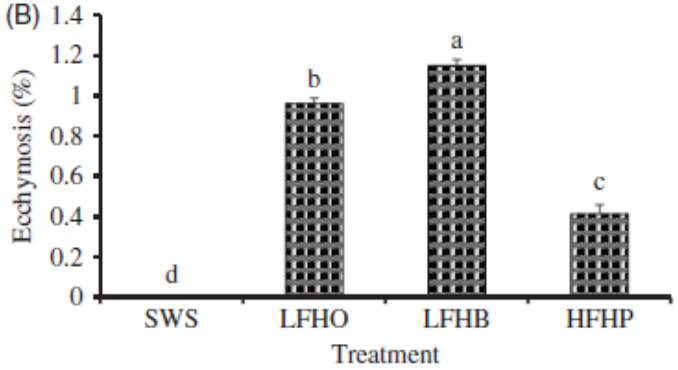
Shoulder



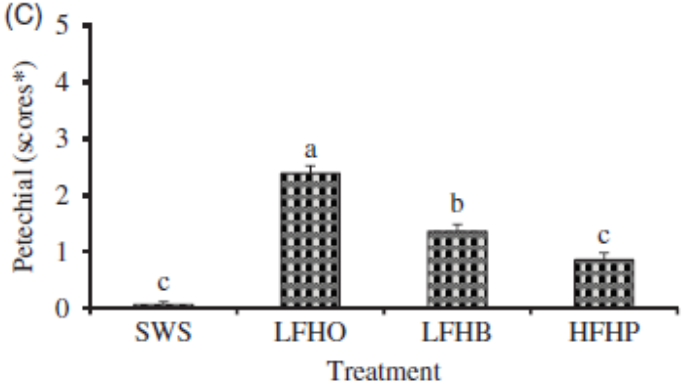


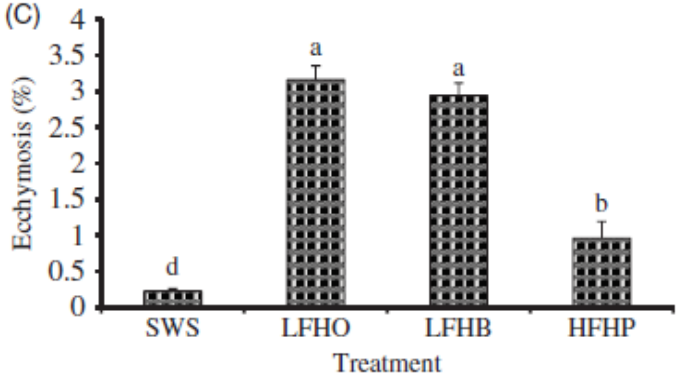
Loin





Leg





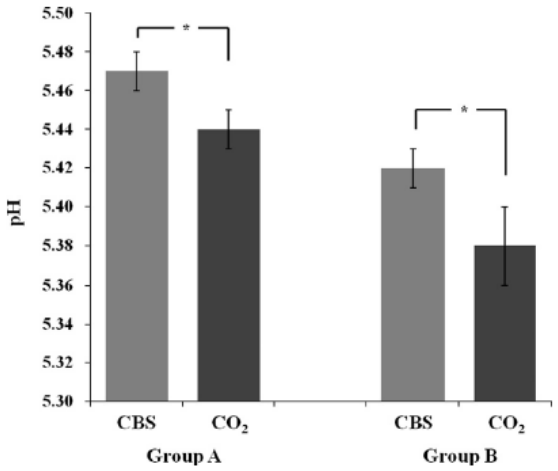
Controlled Atmosphere

The gas controversy

- Is it humane?
  - Reports of aversive reactions to CO_2
    - Gasping, escape attempts
    - 37 sec till collapse
  - But other studies find no such responses.
  - Why?
    - Rate of increase in CO_2 concentration?
    - Genetics?
    - Something else?
- Recent research has focused on improved methods
  - Gas mixtures
  - Gas immersion parameters, e.g. multi-stage CAS systems for poultry

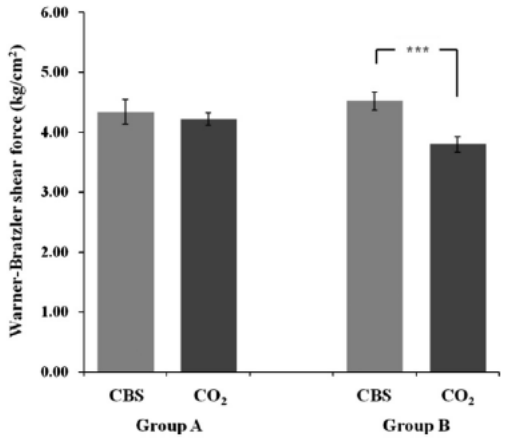
CAS in ruminants

- Rodriguez *et al.* 2015
  - Lambs showed head shaking and sneezing at 10 s;
  - Unconscious for 124 s (90% CO_2)
- Millman *et al.* 2015
  - Goat kids tolerated 20-30% CO_2 (n=12)
  - Loss of posture occurred between 87 and 271 s of exposure
- Kim et al 2013
  - Cattle 620-790 kg (A –lighter, B heavier)
  - 70% CO_2 for 140 sec
  - Compared against captive bolt
    - lower pH, lighter colour,
    - lower shear force in heavy cattle



Source: Kim *et al.* 2013

A- 620-710 kg
B- 720-790 kg



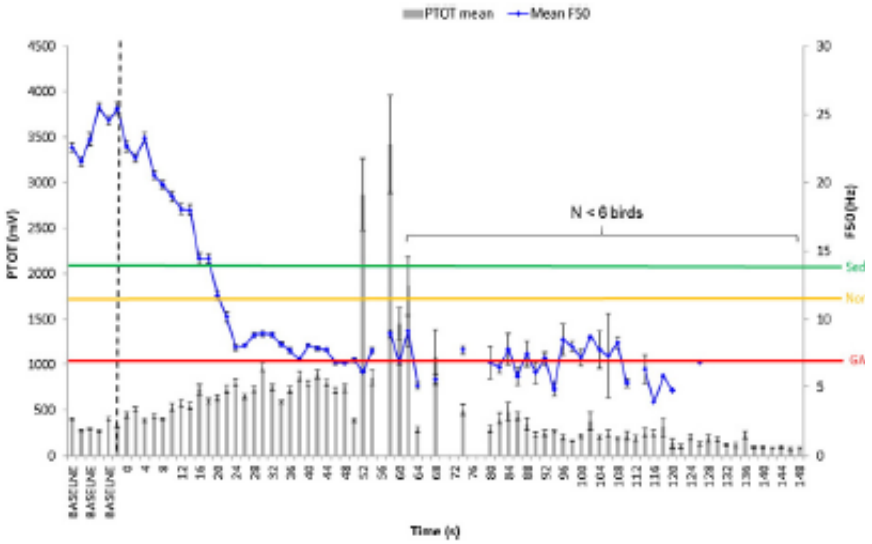
LAPS

LAPS

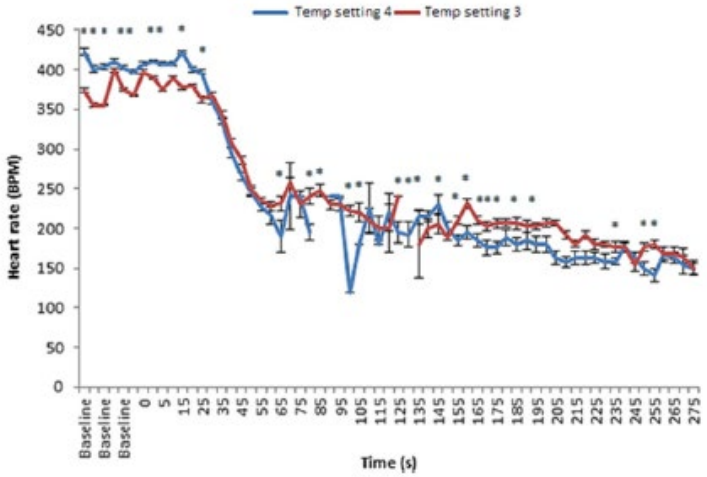
- Concept based on altitude hypoxia
  - O_2 concentration is reduced at altitude
  - Leads to dizziness and fainting
- Controlled decompression over 280 s
  - 80.6 kPa less than atmospheric air
- Open bill breathing seen at 44-57 s
- Loss of posture at 63-97 s
- Convulsions 53-147 s later
- Motionlessness at 178-222 s

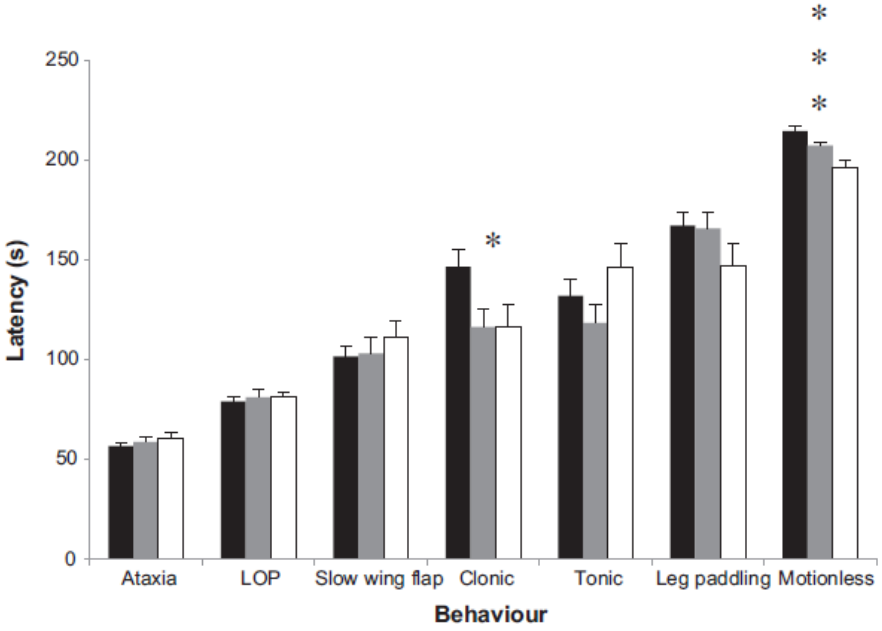
Birds entering the chamber

Birds exiting the chamber



Source: Martin *et al.* 2016





Source: Mackie *et al.* 2016
Temperature can affect responses,
Temperature affects O_2 density in air

Source: TechnoCatch LLC (www.chickencatcher.com)


Source: TechnoCatch LLC (www.chickencatcher.com)

LAPS

- Successful in broiler slaughter
- What about other species?
  - Pigs?
  - Bobby Calves?
- What about on-farm disposal
  - Unwanted piglets
  - Poultry
  - Disease outbreaks?

Source: TechnoCatch LLC (www.chickencatcher.com)

The Future

On the horizon

- SPUC
  - Single Pulse Ultra-High Current
  - Hoping to eliminate blood splash issues
  - 5000 V; 70 A; 50 ms
  - Successes in cattle
- DTS: Diathermic Syncope ™
  - Recent research in cattle
- TOMS
  - Transcranial Oscillating Magnetic field Stunning
  - Similar to transcranial magnetic therapy (TMS)
  - Successes in broiler chickens

SPUC, TOMS and DTS are potentially reversible

SPUC

- Pulsed ultrahigh current (5000 V, 70A)
- 38 cattle successfully stunned
- Unconsciousness lasted up to 4 min
- Elimination of clonic phase

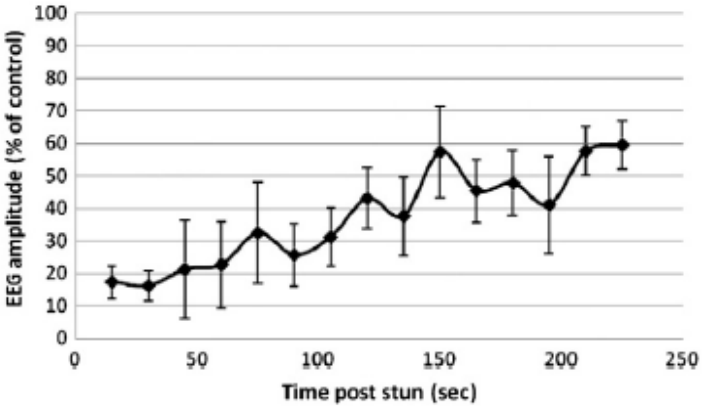


Fig. 2. EEG amplitude following UHC2 stun.

Source: Robins *et al.* 2014

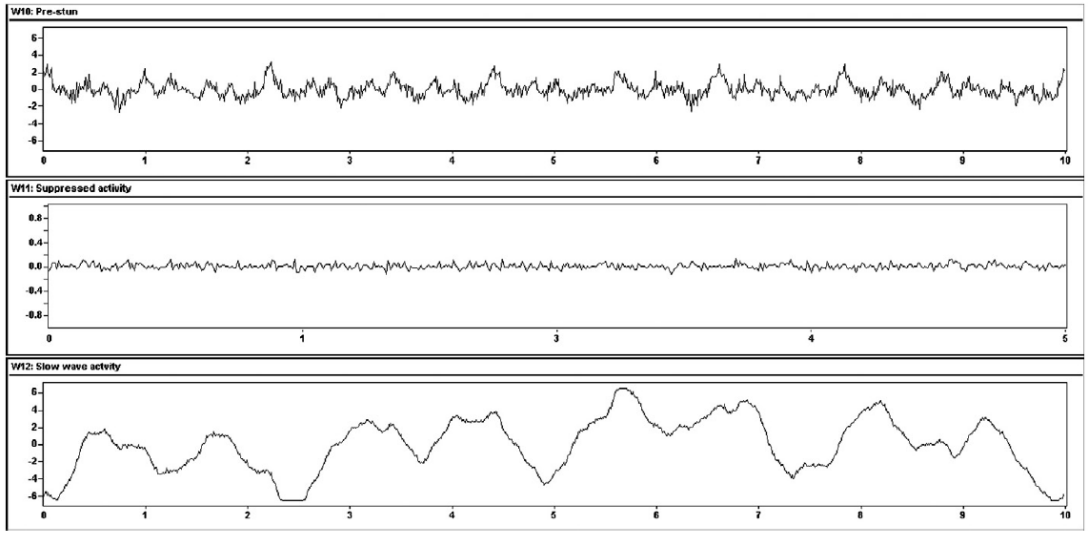
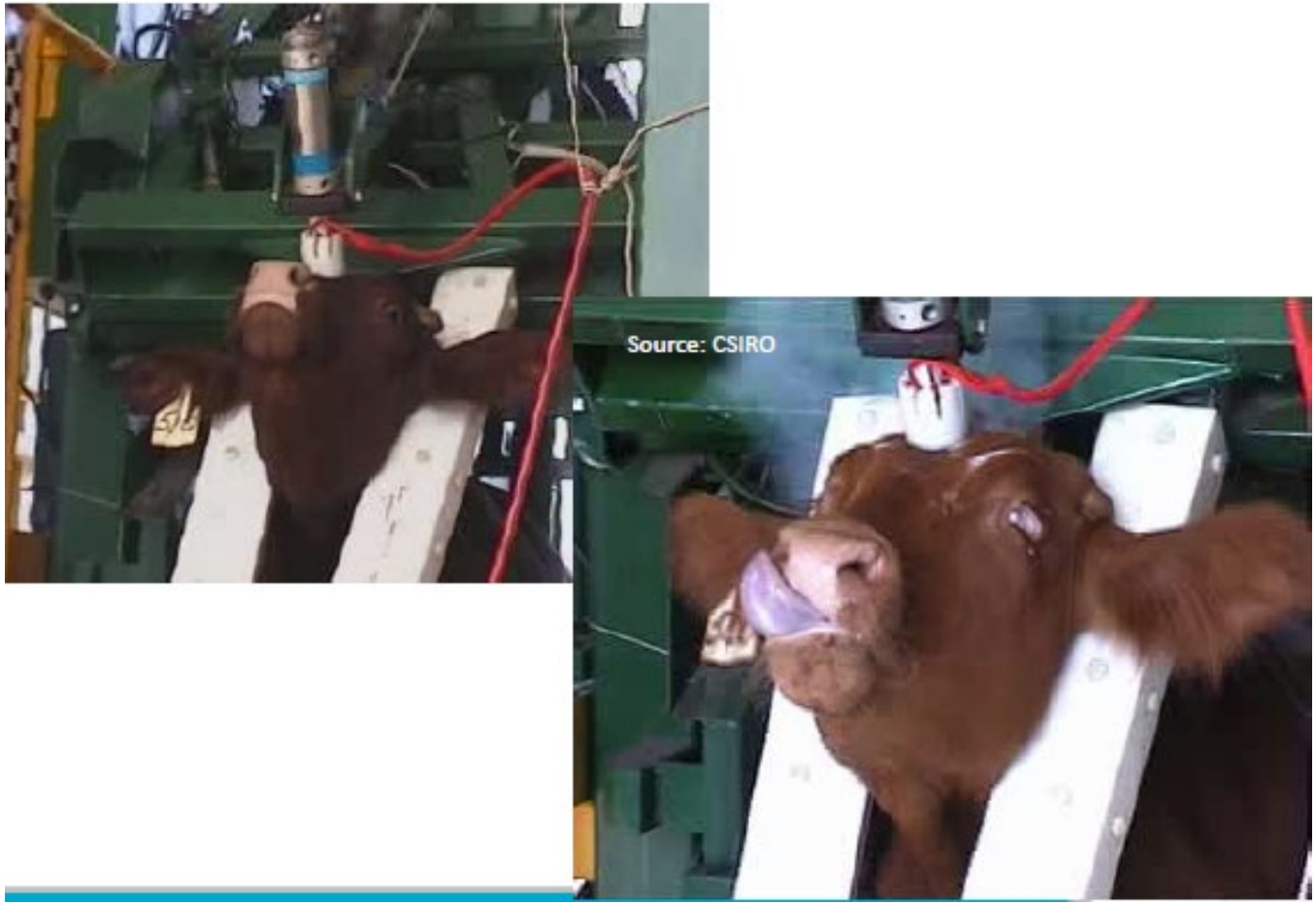


Fig. 1. An example of the electrical recording before and following a UHC2 stun, with the Y axis representing voltage (mV) and the X axis time in seconds.



- No ongoing research in Australia
- But interest from the UK Humane Slaughter Association
- Can the animal recover?

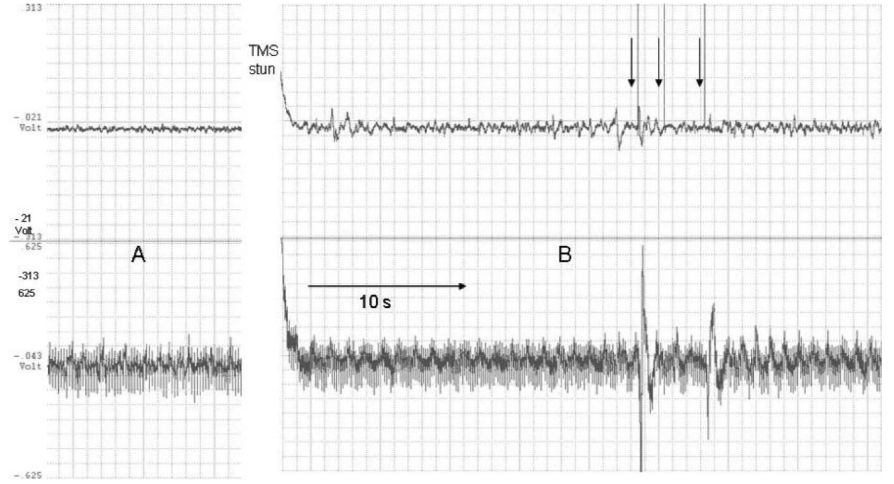
TOMS

- Broilers unconscious for 15-20 s post application (n=25)
- Loss of muscle tone
- Loss of behavioural responsiveness

Can it be upscaled to other species?

Can the animal recover?

Is work continuing?



EEG (upper) and ECG (lower) (A) before and (B) after TMS stunning using a double coil with a power of 51% (↓ administration of a comb pinch).

Source: Lamboij *et al.* 2011

DTS: Diathermic Syncope ®

- Electromagnetic energy (922 MHz)
  - Focused into the brain
  - Volumetric heating
- Induced Hyperthermia
  - Above 43° C
  - Below 50° C

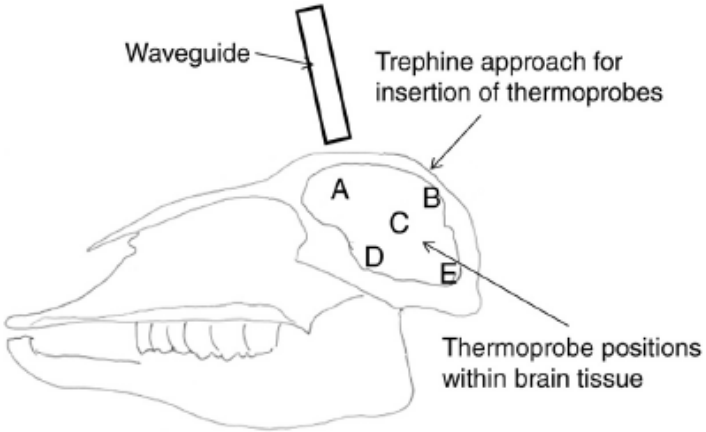


Fig. 1. Schematic diagram of cadaver experiment showing position of wave-guide and thermoprobes.

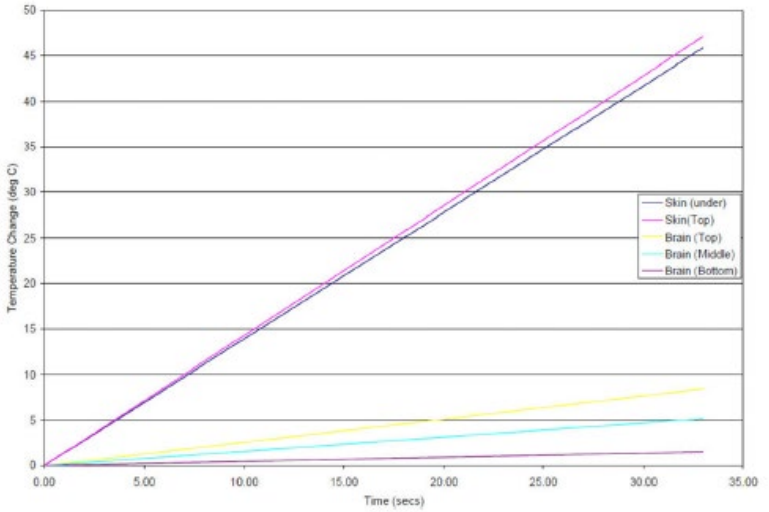
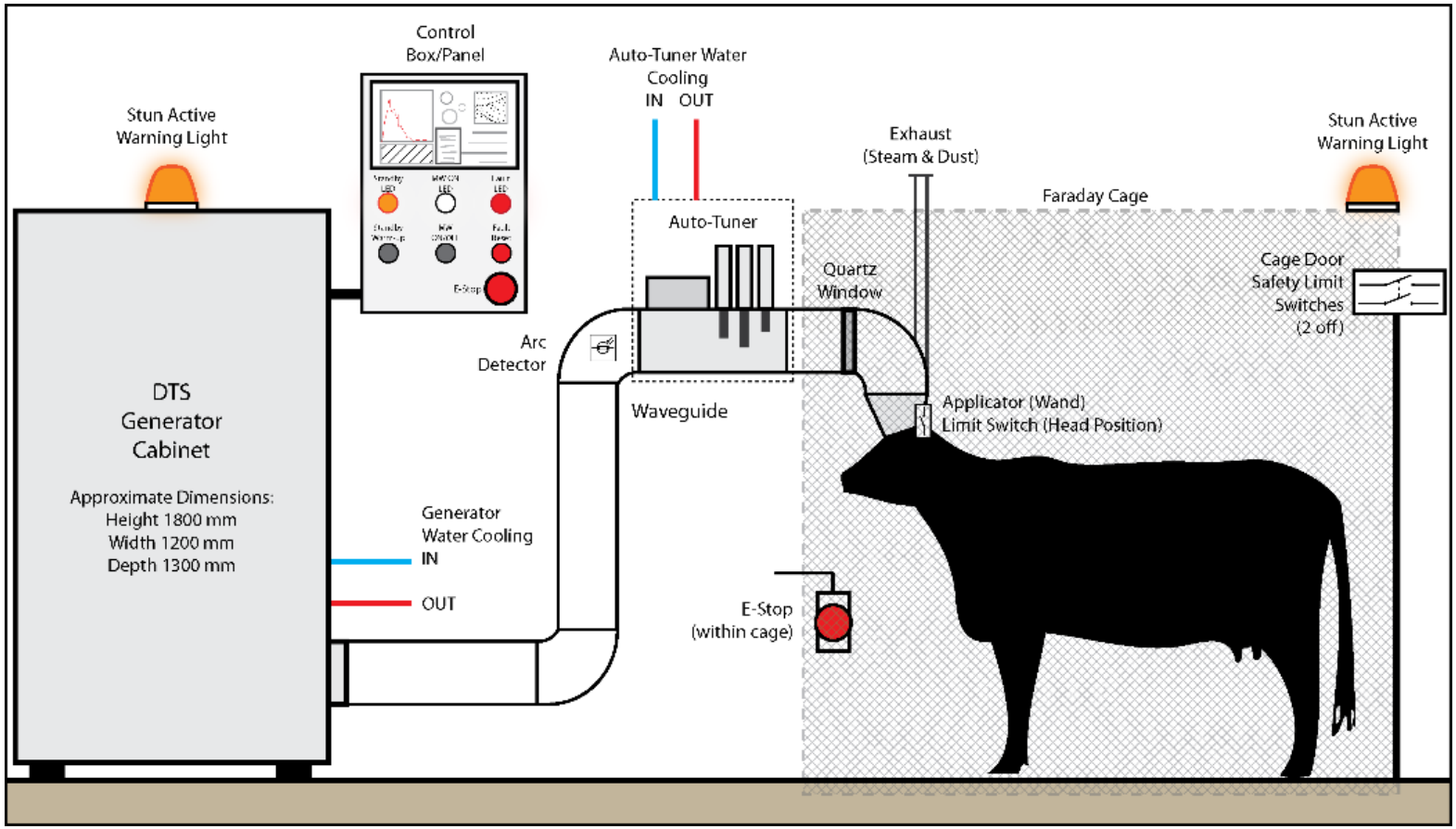


Fig. 3. Temperature change in cattle heads during microwave energy application (mean data from 12 cadaver heads treated at 922 MHz).

McLean, D., Meers, L., Ralph, J., Owen, J.S. & Small, A. 2017. *Res. Vet. Sci.,* 112**,** 13-17.

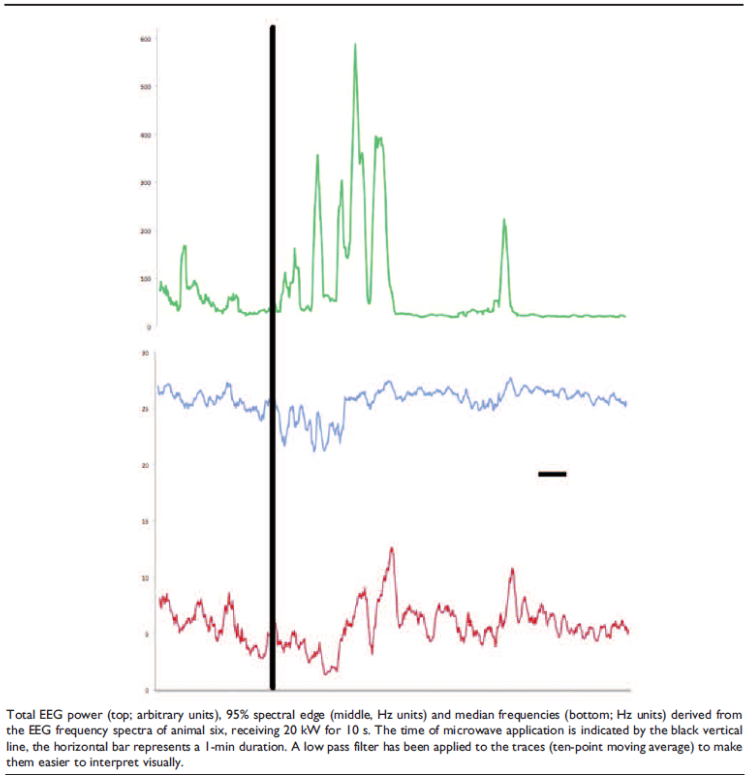
DTS: Diathermic Syncope ®



Source: Advanced Microwave Technologies

Anaesthetised cattle trials

- 10 anaesthetised cattle
- Range of applications
  - 20 kW for 15 s (300 kJ); 20 kW for 10 s (200 kJ); 30 kW for 10 s (300 kJ); 30 kW for 5 s (150 kJ); 12 kW for 25 s (300 kJ)
- All applications resulted in seizure-like EEG
- EEG suppressed for 37 s to 162 s
- Lower kW applications were slower to take effect



Total EEG power (top; arbitrary units), 95% spectral edge (middle, Hz units) and median frequencies (bottom; Hz units) derived from the EEG frequency spectra of animal six, receiving 20 kW for 10 s. The time of microwave application is indicated by the black vertical line, the horizontal bar represents a 1-min duration. A low pass filter has been applied to the traces (ten-point moving average) to make them easier to interpret visually.

Rault, J.L., Hemsworth, P.H., Cakebread, P.L., Mellor, D.J. & Johnson, C.B. 2014. *Animal Welfare,* 23**,** 391-400.

Pilot study on conscious animals

- 18 Aberdeen Angus cross bred heifers
  - 350-400 kg liveweight
  - Rested in lairage 4 days
  - Low-stress handling
- 7 assigned to captive bolt
- 11 assigned to DTS
  - 3 high penetrative energy
    - (>290 kJ)
  - 4 low penetrative energy
    - (<200 kJ)
  - 4 intermediate (200-290 kJ)

MEASURES

- Behaviour and reflexes (live)
  - Corneal reflex
  - Palpebral reflex
  - Pupillary response
  - Focusing and following
  - Nose prick
- Behavioural responses (video)
- EEG
- Carcase and meat quality
- Endocrinology

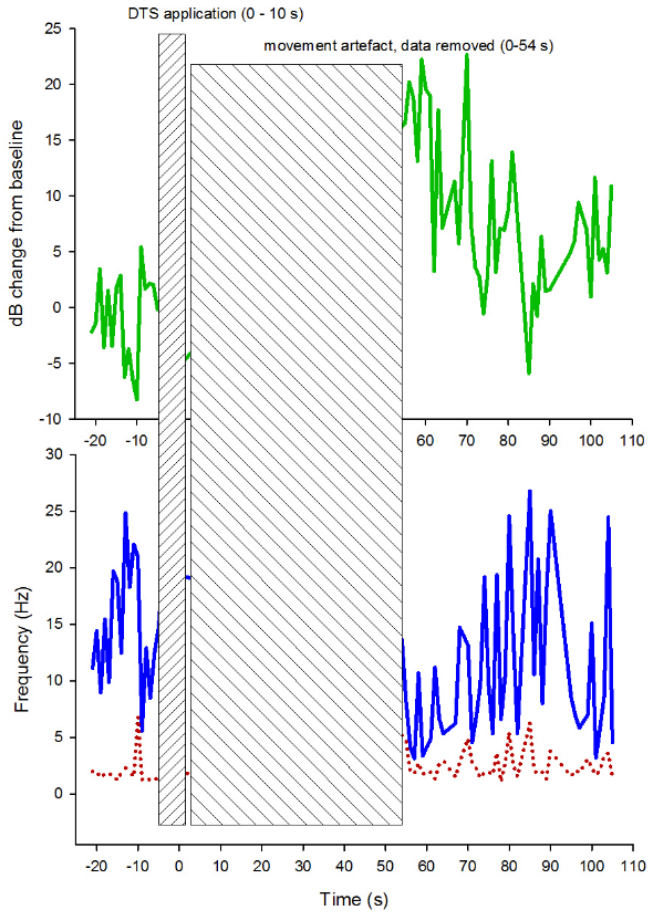
Outcomes of pilot study 2014-15

- DTS induced insensibility:
  - EEG suppression for 3-4 minutes.
- DTS animals remained unresponsive to stimuli:
  - No evidence of the eye beginning to focus and follow movement for 3-4 minutes post energy application;
- DTS animals maintained rhythmic breathing and a strong heart beat throughout the period of insensibility;
- Two animals showed evidence of return to consciousness, including the righting reflex, after around 4 minutes

Source: CSIRO

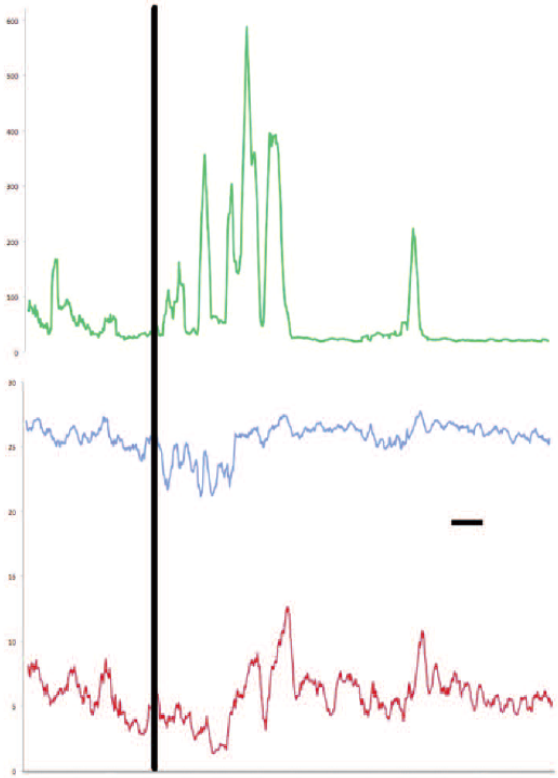
EEG

Pilot study Animal 16: 184 kJ



Small et al 2019: 200 kJ

Rault et al 2014: 200 kJ



Total EEG power (top; arbitrary units), 95% spectral edge (middle, Hz units) and median frequencies (bottom; Hz units) derived from the EEG frequency spectra of animal six, receiving 20 kW for 10 s. The time of microwave application is indicated by the black vertical line, the horizontal bar represents a 1-min duration. A low pass filter has been applied to the traces (ten-point moving average) to make them easier to interpret visually.

Pilot study outcomes 2

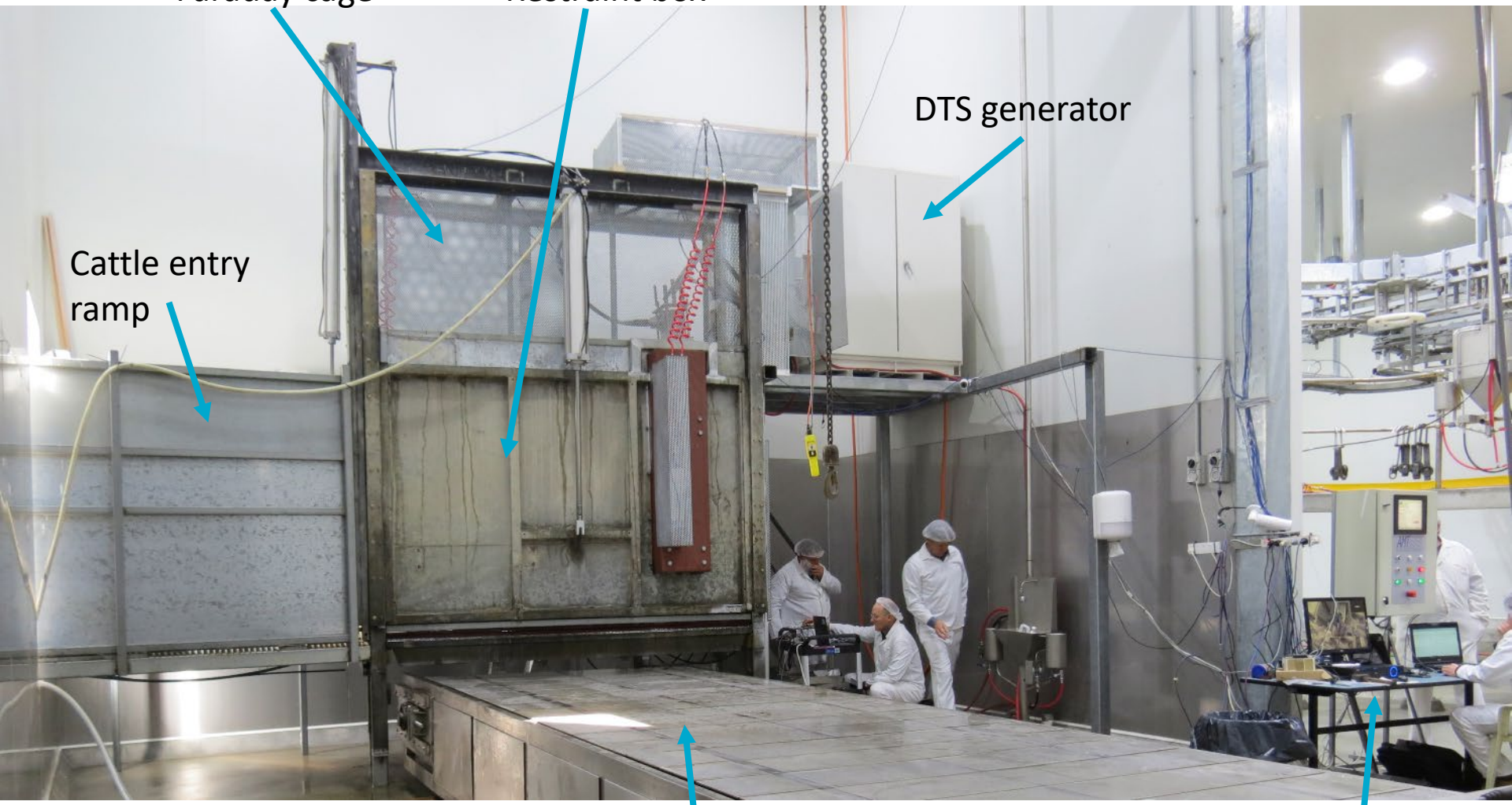
- DTS produces comparable endocrine responses in cattle to those stunned using captive bolt.
- DTS produces comparable post slaughter meat quality in beef carcases to those stunned using captive bolt.

  - Pilot study utilized a delivered energy range of 100 - 300 kJ
    - 100 kJ – shorter duration of stun
    - 300 kJ – likely to be non-recoverable

- No evidence of blood splash
- No significant differences in:
  - pH decline
  - Shear force
  - Drip loss
  - Colour
  - Lipid oxidation
  - ACTH
  - Cortisol
  - Catecholamines
  - β-endorphin

Current activities

- Refinement of applicator wand
  - Reduce skin heating
  - Improve energy transfer
  - Improve consistency of delivery
- Identify critical limits to energy/power settings
  - Reversibility
  - Range in cattle sizes and types
    - 150 cattle processed to date (+ 11 pilot study and 10 anaesthetised)


Faraday cage
Restraint box
DTS generator
Cattle entry ramp
Roll-out conveyor
DTS control station


04/10/2017 09:38:30
Head captured for EEG recording
Animal in restraint box
Water reservoirs to absorb any leaked energy
Nose comforter
Waveguide (retracted)

Energy parameters; current work, batch 1

Day 1 (4/10/17)	Day 2 (5/10/17)	Day 3 (6/10/14)
1 * 360 kJ at 30 kW 2 * 300 kJ at 30 kW	2 * 300 kJ at 30 kW 1 * 275 kJ at 30 kW 2 * 250 kJ at 30 kW 4 * 225 kJ at 30 kW 1 * 225 kJ at 20 kW	1 * 300 kJ at 30 kW 1 * 275 kJ at 30 kW 3 * 275 kJ at 20 kW 1 * 200 kJ at 20 kW 1 * 200 kJ at 15 kW
3 cattle	10 cattle	7 cattle

- DTS generator delivers entire energy set (kJ) unless emergency stop is activated (manual or safety cut-out)
- Reducing Power (kW) reduces the rate of heating

Summary of behavioural observations

- 4 animals rendered dead (300 – 360 kJ)
- 3 animals not fully stunned (major energy leakage in 2; low power 15 kW used in 1)
- 17 animals unconscious based on loss of posture and absence of reflexes (despite leakage issues). Reflexes returning between 100 and 170 s post collapse.
  - In a commercial situation, exsanguination would be expected to occur within 45 s of collapse – this was delayed in the study for EEG recording.

More to come

- Another 130 data sets in data collation and pre-analysis phase
  - Duration of insensibility between 3 and 5 minutes
  - Use of reflexes to assess unconsciousness
  - Evidence of recoverability observed (righting reflex and visual awareness)

Comparison with head-only electrical stunning (literature)

	Electrical stunning	DTS
Time from application to loss of posture	4 – > 20 s	1 – 8 s
Time from loss of posture to return of reflexes	31 – 90 s	100 – 170 s

Thank you

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