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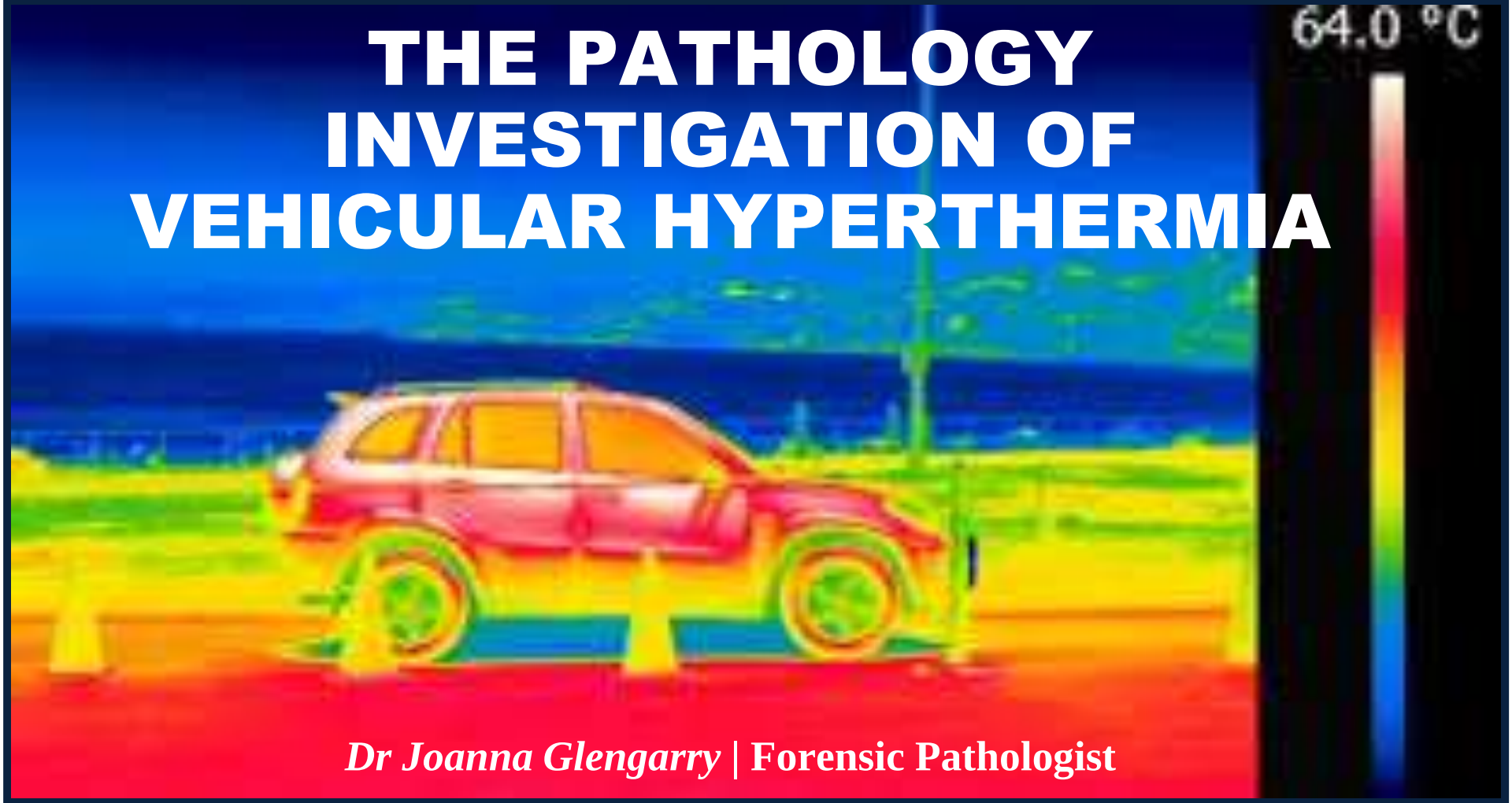
"KIDS IN CARS"

THE PATHOLOGY INVESTIGATION OF VEHICULAR HYPERTHERMIA



Dr Joanna Glengarry | **Forensic Pathologist**

THE AGE

NATIONAL VICTORIA

Seven children locked in cars, despite Melbourne's high temperatures

By Marissa Calligeros
Updated 22 January 2015 — 9:22am, first published at 8:59am

THE AGE

NATIONAL VICTORIA AMBULANCE

18 kids left in hot cars, as Minister begs 'do the right thing by kids'

By Liam Mannix
7 December 2018 — 5:00pm

Boy dies inside car after dad's memory lapse

1:00AM October 4, 2013

Woman who partied while her children died in hot car jailed for 40 years for 'horrific case' of neglect

'She knew those kids were back there. She left them in that car,' country sheriff says

Michael Brice-Saddler | Tuesday 18 December 2018 13:35 |

Five kids trapped in hot cars, as temp soars

Victoria will face its hottest day in almost three years on Friday as firefighters brace for out of control and unpredictable fires across the state.

KIDS IN CARS: THE PROBLEM

- Motor vehicle related fatalities in children left in cars are well documented in literature
- Infants and children are a vulnerable population

- Ambulance Victoria responded to 225 cases of children left in cars during the month of December 2015
  - On a single 37 degree day, there were 13 callouts[1]


The Sydney Morning Herald

NATIONAL NSW TRAGEDY

Death of toddler sparks police investigation in Wagga Wagga

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1. www.premier.vic.gov. au

KIDS IN CARS: THE PROBLEM

- USA Data – 700 infants/children have died due to vehicular hyperthermia in 19 years (average 37 per year)[2]
- VIFM – 5 cases in 18 years[3]
- Israel – 8 cases in 21 years[4]
- Increasing incidence with time:
  - Thought that incidence increasing since back seat car seat placement promoted[5]

HOT CARS Act 2017 (USA)

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2. Quinton R. 2017 FP QAP FR-B/FR-10
3. Personal iCMS search - JOG
4. Adato B. Eur J Pediatr 2016;175:1249-52
5. Sens M. In: FP of Infancy and Childhood. Collins/Byard. Ch27.

KIDS IN CARS: THE LAW

- Multiple laws in the different jurisdictions with the following general themes:
  - Providing the child with the *necessaries of life*: safety and supervision, food, clothing and accommodation.
    - ACT, NSW, SA, WA.
  - Leaving a child in a *dangerous situa*tion (where death or injury foreseeable), not being fed, not clothed or provided with accommodation.
    - ACT, NSW, NT, SA, WA.
  - Law allowing for the *removal* of a child from a dangerous situation without an adult present.
    - Custody related rather than charges.
    - ACT, NSW, NT, NZ, SA, WA.
  - Leaving a child for an *unreasonable time without supervision*.
    - NZ, QLD, TAS, VIC.
  - Leaving a child *unsupervised in a motor vehicle*, where the child is likely to become emotionally distressed or have its health endangered.
    - WA

KIDS IN CARS: THE LAW

- *Prosecutions[6]:*
- Variable rates
  - Many considered “tragic accidents”
  - Highest prosecution rates in unrelated carers and where drugs/etoh involved
  - “White Collar” 23% prosecution rate
  - “Blue Collar” 86% prosecution rate
- 83-92% conviction rate

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6. Quinton R. AFP 2016;6(4):657-62

DIAGNOSIS

* *Hyperthermia* – elevated body temperature

* *Heat stroke* – clinical syndrome of hot, dry skin with CNS abnormalities (e.g. coma/seizures) and a body temperature greater than 40 degrees

* A *heat-related death* is one in which exposure to high ambient temperature either caused the death or significantly contributed to it (NAME Position Paper)[7]

Circumstances and meticulous scene examination *

Body, scene, car temperatures *

Medical records and admission observations and test results *

Rule out other causes of temperature elevation (rare) *

Screen for injury/neglect, overall “condition” of the infant *

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7. Donoghue E. Am J Forens Med Pathol 1997;18(1):11-14

AUTOPSY FINDINGS

MINIMAL OR NONE

NON-SPECIFIC

- Haemorrhagic findings:
  - Petechiae, subendocardial haemorrhage, serosal membrane haemorrhage
- Prolonged survival / resuscitated:
  - DIC with microthrombi, rhabdomyolysis, brain swelling, MOF, AKI, hepatic centrilobular necrosis, GI ischaemia
- Advanced decomposition
  - Deaths in heatwave conditions
- Dehydration pattern with biochemical testing

FACTORS AFFECTING AIR TEMPERATURE IN A VEHICLE[8]

- *Sunlight intensity*
  - Sun position in sky, season, time of day, latitude/hemisphere, cloud cover
- *Ambient temperature*
  - Temperature of the vehicle's immediate environment
- *Duration of exposure*
- *Wind*
  - Cools the outer metal skin of the vehicle and prevents hot air from stagnating around the vehicle
- *Car colour*
  - Dark colours absorb a greater fraction of the sunlight falling on the vehicle
  - Approx 6 degree temp difference between black and metallic silver vehicles
- *Windows*
  - Minimal effect when 'cracked', need to be fully open for meaningful effect
- *Position in vehicle*

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8. White DR. Expert Opinion F2015-0767H.

THE SCENE

Hazardous thermal thresholds may be reached even with mild ambient temperatures [9]

SUMMER
Most rapid - 40 degrees in ~100 mins

WINTER
Slowest – 40 degrees in ~300 mins

AUTUMN OR SPRING
Intermediate - 40 degrees in ~200 mins

- Rapid rise in first 15-30 mins[10]
- 80% of max temp reached in 30 mins[11]
- Takes approx. one hour for the interior temperature to stabilize to near the maximum temp

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9. Grundstein AJ. Forensic Sci Med Pathol 2015;11:13-19.
10. McLaren C et al. Pediatrics 2005;116(1):e109-112.
11. Booth JN et al. Forens Sci Med Pathol 2010;6:99-105.

THE MOST CONSISTENT AUTOPSY FINDINGS

MINIMAL OR NONE

NON-SPECIFIC

- *T*he main findings in hyperthermia deaths relate to a coagulopathy[10,11,12]
  - Cutaneous, conjunctival petechiae
  - Intrathoracic petechiae
  - Haemorrhages of serosal membranes
  - Thymic petechiae
  - Subendocardial haemorrhage
  - Intramuscular haemorrhages e.g. psoas haemorrhage
  - Retroperitoneal haemorrhage
- Petechiae are non-specific however and seen in other deaths: SIDS, asphyxia, sepsis, vasculitis, violent coughing, other coagulopathies, CPR(?)

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10. Milroy CM, Parai JL. Ch 2. In: Essentials of Autopsy Practise (Rutty GN, ed). 2013

11. Krous HF et al. Am J Forensic Med Pathol 2001;22(4):374-82.
12. Adato B et al. Eur J Pediatr 2016;175:1249-52.

COAGULOPATHY AND SURVIVAL: CLINICAL DATA

- Commonly held misconception that haemorrhagic findings are only present with prolonged survival e.g. in hospital.
- Heptocellular necrosis, rhabdomyolysis and DIC are indeed described after 6 hours and in those dying in hospital.
- However, early findings are also seen:
  - Cases of children/infants with heat exposure within a vehicle of as little as **one hour** had intrathoracic petechiae observed, even when deceased shortly after being found or on arrival at hospital[13].

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13. Krous et al. Am J For Med Pathol 2001;22(4):374-82.

COAGULOPATHY AND SURVIVAL: EXPERIMENTAL DATA

- Data from patients subjected to therapeutic whole body hyperthermia (for cancer treatment) demonstrate the early (<3h) development of coagulation disturbance[14].
- Studies on pilgrims travelling to Mecca who succumbed to heat stroke showed coagulation abnormalities at the time of admission to hospital[15,16].
- Canine models of whole body hyperthermia[17]:
  - After 90 mins of warming, body temperature reached 40 degrees and the following was noted -
    - Reduced numbers of platelets.
    - Fibrinolysis (fibrin degradation products detected).
    - APTT prolongation.

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14. Strother SV et al. Thrombosis Research 1986; 43; 353-360.
15. Bouchama A et al. Thromb Haemost. 1996;76(6):909-15.
16. Al-Mashhadani SA et al. Platelets 1997;8(1):37-42.
17. Diehl et al. American Journal of Hematology 2000;64:262–270.

IS DEHYDRATION A USEFUL FINDING?

Biochemical assessment for dehydration is described as being a necessary procedure to aid in the diagnosis of hyperthermia. But how useful a test is it?

NORMAL RESULT

DEHYDRATION PATTERN

Increased sodium, chloride, urea, creatinine

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IS DEHYDRATION A USEFUL FINDING?

- *Scant data on biochemical findings in paediatric vehicular hyperthermia deaths.*
- Study of paediatric hyperthermic deaths (cars, beds)[18]:
  - Dehydration in 1/3 of cases of vehicular hyperthermia death.
    - Study does not describe how dehydration diagnosed (clinical, biochemical).
- Death may occur too rapidly for abnormalities to occur[19].
- VIFM Cases:
    - Two cases – no biochemical abnormality – *died in car*
    - One case equivocal (mild sodium and chloride elevation only) – *died in car*
    - Two cases with MOF including renal failure – *died in hospital*

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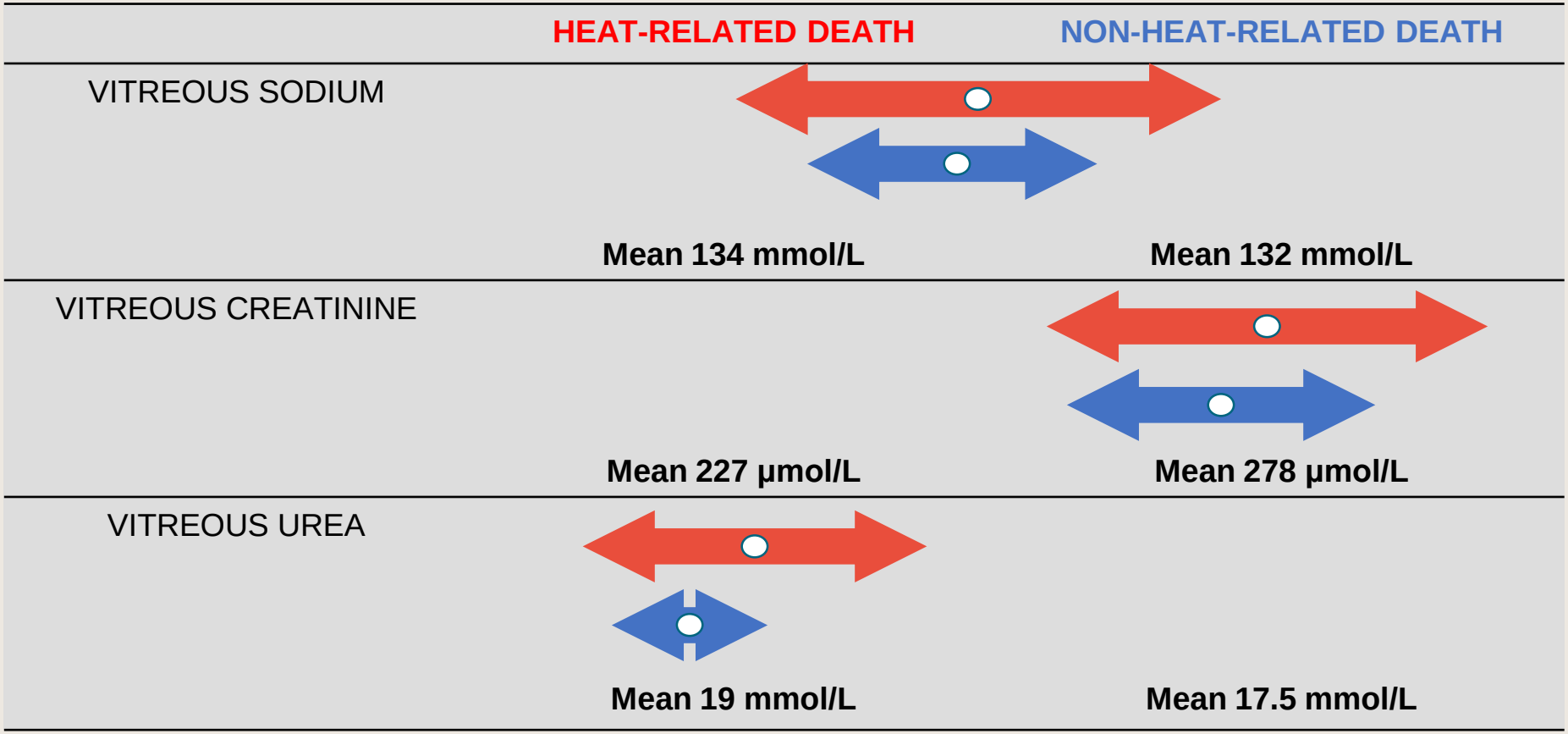
18. Krous HF et al. Am J Forensic Med Pathol 2001;22(4):374-82.
19. Quinton R. AFP 2016;6(4):657-62.

IS DEHYDRATION A USEFUL FINDING?



- South Australian study of heat related deaths[20] → Adults.
  → Heatwave conditions.
  → Comorbidities.

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20. Herbst J et al. J Forensic Legal Med 2014;22:73-8.

HYPERTHERMIA AND PM BIOCHEMISTRY

- **Comprehensive review in 2013 Swiss study[21]:**
- Dehydration pattern of electrolytes.
  - Creatinine increases may be due to renal failure or rhabdomyolysis.
- Myoglobinuria.
  - IPX positivity for myoglobin in renal tubules.
- Cardiac troponin may be elevated (serum, CSF, pericardial fluid).
  - Most marked when histologic myocyte injury seen.
- Tryptase elevated – BUT – cases of drug-induced hyperthermia
- CRP not elevated.
- Procalcitonin *may be* elevated.
- *Conclude that the diagnosis of hyperthermia cannot solely be based on biochemical findings.*

Catecholamines
Chromogranin, serotonin
ACTH, GH

21. Palmiere and Mangin. Int J Legal Med 2013;127:93-102.

HEAT-RELATED DEATH: DEFINITION[22]

- *A death in which exposure to high ambient temperature either caused the death or significantly contributed to it.*
  - With the reasonable exclusion of other causes of hyperthermia.
  - Antemortem body temperature >40 degrees C: certify as hyperthermia/heat stroke.
  - Deaths may also be certified as heat stroke or hyperthermia with lower body temperatures when cooling has been attempted prior to arrival at the hospital and/or when there is a clinical history of mental status changes and elevated liver and muscle enzymes.
  - If the antemortem body temperature cannot be established but the environmental temperature at the time of collapse was high, an appropriate heat-related diagnosis should be listed as the cause of death or as a significant contributing condition
  - It is appropriate to certify a death as heat-related if the investigation provides compelling evidence of continuous exposure to a hot environment and fails to identify an independent cause of death.

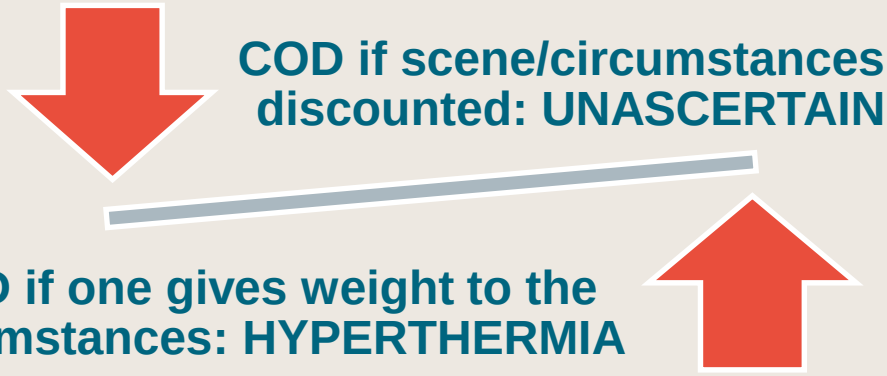
22. Donoghue et al. Am J For Med Pathol 1997;18(1):11-14..

PUTTING IT ALL TOGETHER

- We accept that the interior of a car *can be* a hazardous place for a child …..
- ….. but is it a lethal environment?
- How do we approach formulating a reasonable COD?

CAUSE OF DEATH AND BIAS

- The diagnosis of INFANT VEHICULAR HYPERTHERMIA is based on:
  - A constellation of *non-specific* autopsy findings (usually).
  - In the setting of circumstances which indicate the infant was in an unsafe environment, recognized to be associated with heat stress.
  - Without an apparent competing cause of death.
- That is, the autopsy findings do not, *by themselves*, indicate hyperthermia.
- <u>The role of contextual bias</u>?



CONCLUSIONS

- The inside of a car may be a hazardous environment for an infant or child left unsupervised as they are a vulnerable group and even in mild weather, the internal temperature may reach hazardous conditions.
- Death investigation requires scene, body and ambient temperature information and careful scene reconstruction.
- Autopsy findings may be non-specific and the most consistent findings are haemorrhagic.
- Biochemical analysis should be performed, where possible, and is useful if a dehydration pattern is seen. However a normal finding does not negate the diagnosis of hyperthermia.
- We should be cognizant of contextual bias in the COD determination – but – do not shy away from making the diagnosis of hyperthermia.
- Acknowledge what the pathology says and what the circumstances suggest.

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THANK YOU