PAVA

This paper has been commissioned to answer questions about PAVA and its possible use in childhood, its medical effects, whether it may developmental impacts e.g. on eyes, the policy of not placing people into prone restraint after the use of PAVA, the risk of mutagenesis, or cancer arising in a person after PAVA has been sprayed upon them.

To answer these questions and to provide notes that help to explain the scoring of the risk matrix for the use of PAVA, background information is given in this paper. The questions posed in the first paragraph are answered in the text under specific headings written in italics.

Content

This document starts by outlining the chemical composition of PAVA, and the set testing methods and standards required of manufacturers in producing the PAVA device. These standards should be considered in terms of the operational use in a dynamic setting as the tests to confirm that these standards are met for PAVA devices are performed in a static setting.

The mechanism of action of PAVA and Its medical effects are described and the impact in terms of the primary medical effects on the child who is sprayed, and possible secondary effects due to being incapacitated is discussed.

The psychological impact is being considered, I understand, by clinical psychologists separately. However, it is noteworthy to think about the relative disproportionate percentage of children with recognised problems in cognitive and processing abilities in the secure estate. This is touched upon towards the end of this paper.

All the references that are mentioned in this paper have been sourced from available materials in the public domain. Scientific literature has been searched via the search engine, Pubmed, using separate terms such as PAVA, irritant chemical spray and incapacitating fluids/liquids. From the results of these search, the references in the resulting papers found by the search were also checked to see if they were relevant. There was no specific literature on the use or medical effects of PAVA in children.

There may be additional material that is not readily accessible so that there may have been further developments in relation to PAVA that are not included in this paper.

Constituents of PAVA spray

PAVA spray is a liquid composite of pelargonic acid vanilylamide which is a manufactured product, related to capsacin, a natural compound found in chilies.

There are 2 forms of PAVA, PAVA 1 and PAVA 2 – the latter is not flammable. Both formulations comprise of 0.3 (+/- 0.03%) PAVA, with PAVA 1 & 2 having alcohol as intrinsic solvent component.

In 2002, the HOME OFFICE commissioned the Centre for Applied Science and Technology (CAST), (integrated into the Defence and Science Technology Laboratory in 2018) to established fixed testing methods and standards that must be met by manufacturers of PAVA spray devices. Work has continued on developing the standards since then, the last publication being 9 years ago.

(REFERENCE Home Office CAST standard for police irritant sprays: CS and PAVA, publication no: 23/14 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/337910/standard-police-irritant-sprays-2314.pdf).

CAST did compare CS irritant agent with PAVA in 2004, with a more favourable features being noted for PAVA, (published in 2014), which has led to PAVA being the preferred chemical irritant as it has a better profile than the matched CS irritant agent.

(REFERENCE Comparison report on CS and PAVA sprays: Operational and Toxicological aspects publication number: 24/14 www.gov.uk/government/publications/comparison-report-on-cs-and-pava-sprays)

PAVA spray is delivered as a jet from a specially developed type of cannister. The standards set by CAST relate to the cannister, how it delivers the spray, its accuracy and performance characteristics. These are standards that must be met before any PAVA spray device could be recommended for being issue to UK Police Services.

CAST standards required for a PAVA spray device

Some of these standards will be described as they are important when regarding possible medical side effects, as the methods and standards are very precise for testing the PAVA device. However, the operational circumstances may not adhere to the testing conditions for obvious reasons.

The testing standards which could impact the child medically are the following (please note that there are other standards, but these have been picked out for their possible medical impact and will discuss each one in turn):

1 Assessment of spray patterns
2 Determination of discharge rate
3 Determination of impact pressure of spray to solid surfaces

Other CAST standards include trials to determine the accuracy and handling qualities of the PAVA spray device, performance at extremes of temperatures, assessment of spray flammability. These are detailed in the paper, referenced above.

PAVA is active in causing a burning sensation and pain if it reaches the conjunctiva. It is less likely to cause these features if it goes onto skin or hair or any other part of the body or clothing and so be much less effective as an irritant spray in terms of incapacitating the person. There may be secondary effects to other people such as staff who come into close proximity to the affected person.

1 Assessment of spray patterns for a standard PAVA device

The standard expected for the spray pattern of a PAVA device is that, from a distance of 2m, 80% of the PAVA comes to lie within a circle of 15cm diameter after a 0.5 second burst of spray.

Further away from the testing paper, the subsequent dispersal area increases.

The practical implication is that the majority of the spray is within a15cm circle that should encompass the eyes (noting that 20% of the PAVA spray is outside this area). It is likely, therefore, that the nose and mouth may be affected by the spray. This may lead to medical effects occurring, as seen in the medical section that follows below albeit that serious medical events are not thought to be common (note that there is not specific childhood data that can be found.)

Spraying from further away than 2m increases the range of dispersal with less going to the eye region and more going over other areas of the face. This may impact on its effectiveness, which is dependent on how much PAVA gets to the eyes.

Situations where PAVA is used are often very dynamic situations hence getting to a 2m distance may not always occur. If closer than 2m, then PAVA is delivered to a smaller area (note the section below on the limits on the pressure of a PAVA jet that are tolerated by CAST standards) whilst, as seen above, distances further away than 2m may mean that less PAVA reaches the conjunctiva and so may become less effective.

This is especially so if the target circle of 15 cm does not go over the eyes owing to movement by the child.

If a large volume of PAVA is delivered, as it is sprayed as a jet, there may be run off from the eye area into the mouth and nose, into the respiratory system. The skin may also be affected where the jet comes into contact.

Facial size alters according to age and growth of the child. This is highly variable in childhood - there are data about ranges of facial size in adults but there is a large degree of variation in childhood over the length and width of the face as compared with the adult size of the face. This may mean that there is an increased risk for oral, nasal and respiratory tract being affected by PAVA spray for children.

2 Determination of discharge rate

For this standard, the spray device is discharged for 0.5 second to look at the rate and, therefore, the volume of PAVA that is released. The range for this CAST standard is that the device should have a release rate between 2.5 to 13 ml/sec (meaning, that, for a half second discharge, there could be between 1.25 mls to 6.5mls coming out of the PAVA cannister).
The larger the amount that is discharged, the more likely it is that spread over the face, into the nose and mouth causing respiratory problems. I am not aware which PAVA device is in use in HMPI so it may be that the volumes are relatively small.

3 Determination of impact pressure spray to solid surfaces

Testing of the PAVA cannister for the pressure of the spray has the nozzle of the device set 15cm from a pressure plate, with the jet directed to the sensor. A one second discharge is delivered and the maximum pressure during that second is recorded.

If the pressure is greater than 40kPa, this is judged to be a failure of the spray device (noting that 40 kPa is equivalent to more than 300 mmHg – please be reminded that adult blood pressure measurement should be 120/70 mmHg so the maximum pressure is more than double that which constitutes maximum arterial blood pressure). This is a significant pressure threshold – what is not clear are the pressures delivered by the PAVA devices as used in the adult estate and if they would be used in the Children's estate.

It would be expected that a jet at this pressure would produce blunt force trauma, and could cause abrasions, bruising and can impact into the eyeball causing damage (see below on the medical section). The pressure exerted on the person will depend on the distance from the nozzle of the PAVA spray device and the duration of the discharge of the device.

Impact on the body and data on the use of PAVA on children

The effects of PAVA on the human body will be discussed below with reference to available literature. There is a paucity of information specifically about its use in children and young people, and medical complications.

Mechanism of action

PAVA acts by temporarily binding on 'pain receptors' that cause intense irritant and severe discomfort. It is said to elicit a greater pain and irritant response than CS gas (PAVA2 notably is inflammable whereas CS gas is flammable).

The receptors that PAVA works on, TRPV1, are a group that are being studied to see if effective pain-relieving medication can be produced, as the pain is very intense. The binding of PAVA is directly onto this receptor. The binding of PAVA to TRVI is reversible so that its duration of action is about 15-30 minutes, i.e., it comes off the receptor usually relatively easily.

(REFERENCE  TRPV1: Structure, Endogenous Agonists, and Mechanisms
Benítez-Angeles M, Morales-Lázaro S, Juárez-González E, Rosenbaum T.
Int J Mol Sci 2020 May 12;21(10):3421.
DOI: 10.3390/ijms21103421
https://pubmed.ncbi.nlm.nih.gov/32408609)
However, the durations of effects on the body as noted by the Faculty of Forensic and Legal Medicine (FFLM) are recorded as taking much longer to return to their normal state.
The most common effects, pain and burning sensation, are made worse by rubbing or trying to irrigate the affected eye(s) with warm water, being in a confined space or in warm environments.

*Medical aspects of PAVA*

The clearest detailing of the medical effects of PAVA are given in a paper from the FFLM, a body that include Forensic Medical Examiners.  This paper was published in 2021; it does not specifically deal with children. This paper is discussed in detail in this section.

(REFERENCE Irritant sprays: clinical effects and management Recommendations for Healthcare Professionals (Forensic Physicians, Custody Nurses and Paramedics)
Published Jan 2021 – for review in Jan 2024
fflm.ac.uk/wp-content/uploads/2021/02/Irritant-sprays-clinical-effects-and-management-Dr-J-McGorrigan-Prof-J-Payne-James-Jan-2021.pdf)

It notes that there is up to 10% failure rate from the use of irritant sprays which may be due to the interaction with drugs, mental health issues or due to acute behavioural disorders.
These will include conditions such as neurodiversity, ADHD, children with mental health disorders and personality conduct problems – all these are seen at a higher rate within the population of children within the secure estate.

The paper notes that the irritant sprays being delivered from 4m may cause injury to the eyes, respiratory tract and the skin, particularly in those with people with chronic conditions such as heart problems or respiratory problems (e.g. asthma). This is at a further distance than the CAST standard sets (i.e. 2m), noting that at 4m, it is likely that the area of dispersal of the spray will exceed the 15cm diameter target that is required.

The authors note that the symptoms and signs are often short lived, though some people do continue to feel the effects for 2.5 hours or longer. The proposed duration to recovery is given in each of the potential medical problems that might be seen following PAVA use, as given below.

In confined spaces or where longer exposure occurs, the paper proposes that symptom and signs may last longer than those put forward in this paper.

The categories of injury are:

A. Eyes
B. Mouth and nose
C. Respiratory tract
D. Skin

For each of these conditions, the injury that might occur is listed alongside the expected duration until recovery is said to be present, the timing of which is given in the accompanying brackets.

<u>For eye injuries</u>

Pain (<30 min)

Excessive tears (lachrymation) (<15 min)

Spasm of the eyelids leading to them becoming shut (<30 min)

Redness of the conjunctiva (conjunctival erythema) (<30 min)

Blurred vision (reduced visual acuity) (<30 mins)

Heightened sensitivity to light (photophobia) (60 min)

Swelling around the eye(s) (periorbital oedema)

Referral should be made if the person is unable to open their eyes after 30 minutes for emergency ophthalmic opinion.

<u>Ocular conditions that may take longer than 30-60 minutes to resolve</u>

Surface damage to the conjunctiva can occur (as noted up to 40kPa is permitted as the maximum pressure of the spray in the CAST standards). This may be due to the pressure of the spray causing damage to the conjunctiva or that there may be corneal abrasions arising from brisk rubbing of the affected eye. A non-specific inflammatory response may be seen, e.g. an iritis (inflammation of the inner aspect of the eyeball) or inflammation over part or all of the globe of the eye (conjunctivitis). These may last much longer than 30-60 minutes, e.g. it may be several days before a conjunctival abrasion heals.

As previously mentioned, the dispersal area at 2m is that 80% of PAVA spray should land within the target area that involves the eyes for maximal effectiveness. As the mid-face develops throughout childhood (the area between the forehead and the top of the upper lip), the circle with a diameter of 15cm may well go over the ocular region, cover the nose and even abut onto the opening of the mouth. This increases the risk in children for oral, nasal and respiratory problems.

Mouth

Burning sensation in the mouth but rarely is vomiting or nausea reported.

Nose

There may be discomfort, pain and a runny nose (rhinorrhoea) (<30 min)

Sneezing, coughing and/or a sore throat may feature

Respiratory system

Shortness of breath, bronchospasm (rare) – (N.B. bronchospasm is seen in acute asthmatic attacks)

Laryngospasm (rarely encountered), tracheitis (inflammation of the trachea), bronchitis (inflammation of the major airways within the lung)

Pulmonary oedema after excessive exposure, developing some 12- 24 hours later (this is rare but may be more likely to occur in people with underlying cardiac problems)

People with pre-existing respiratory disorders such as asthma are at greater risk of significant effects. The paper states that most respiratory symptom and signs should be relieved 15- 30 min following exposure to PAVA.

Dermatological conditions

The burning sensation and reddening of the skin may last up to 24 hours, there may be blistering of the skin (which may take a number of days to subside).

Irregular white patches of skin can be seen owing to loss of melanin pigment in the skin (uncommon).

Treatment for these listed medical conditions

The treatment for many of these conditions listed above is exposure to air (a fan may be useful in moving air around the face), with recovery being seen within 15-20 minutes in most people.

Chemical burns should be treated by prolonged irrigation to remove PAVA and pain relief provided. Such burns and blisters may take several days to heal.

Limited data

The authors note the limitation of data being available regarding PAVA use and its medical effects.

‘Chemical irritants can cause severe injury, permanent disabilities, and in rare cases, death. The true incidence of morbidity (and possible mortality) of irritant spray

remains unknown in the absence of prospective clinical studies of appropriate statistical power.'

The use of PAVA in the adult establishment and medical effects of its use would be helpful. Collecting data about the duration of the effects of PAVA on adults would also be of use, however, caution must be applied when considering translating impact of such data to potential effects on children. There is limited available data from police sources – appendix 1 shows the data from the Metropolitan Police Service with surprisingly few cases being recorded (used in 20 cases over 2 years), noting though that these did include some of the 'Covid years', the number of complaints that were reported through a 5 year period and the results of a survey of detainees (and staff involved) in using a chemical irritant spray. The later shows a mean time to recovery of well over 2 hours.

*Advice not to restrain in the prone position*

In the paper, there is mention of potential harm that might arise in the prone position. It states,

'General principles of minimising risks of death and harm after restraint and control must be observed and restraint in the prone position must be avoided after exposure. If restrained, breathing must be monitored constantly.'

This can be interpreted that the PAVA is not being removed by circulating area and that there is increased risk of a respiratory complication as the concentration of PAVA in these circumstances will remain higher on the mouth, nasal passages and the respiratory system which would increase the likelihood of bronchospasm +/or laryngospasm.

Primary and secondary injury

Primary injury is due to the restraint process and secondary injury arises as a consequence of the process of the restraint, e.g. flailing arms or legs which may hit a wall.
The primary injuries have been looked at in detail on the medical effects section on PAVA.
The secondary injury arise from the incapacitating aspects of PAVA on how the sprayed person can conducted themselves.

The secondary injuries may come about as a consequence of the temporary clinical effects, eg light sensitivity, blurred vision and burning sensation as examples. The impact of these could lead to the child either being vulnerable to harm from other children or they could fall, stumble or otherwise hurt themselves owing to the medical effects of PAVA on them. Staff may be less likely to offer aid immediately if there is a serious risk of secondary effects owing to proximity to PAVA.

Collecting this sort of information about primary and secondary injury would add value in looking at PAVA's role, noting from the case use of PAVA and obtaining feedback in the adult estate from prisoners and staff so as to provide better information about risks associated with PAVA.

For the purpose of the risk matrix, the primary injuries will be noted as determining the risk for secondary injury is not feasible.
As with other risk matrices derived about techniques employed in restraint, this is largely theorectical and requires updating as information becomes available.
The risk matrix will be marked for a child of normal height and weight, in a later phase of adolescence. (With younger ages, the body is less well developed; for example, less muscle mass, less bone density and the higher susceptibility of growth plates to injury are examples where the age of the child may alter the risk of harm).

Reflections on neurodiverisity, austistic spectrum disorders, ADHD, mental health problems and personality conduct problems

The frequency of these conditions is higher within the population of children in the Secure estate. This has important consequences when looking after such children especially in terms of being able to undertake effective and meaningful communication with the children.

For example, there is the need to consider the language used by staff when talking to children, as some children, by way of their development, may be very literal in their processing of information, e.g. ‘Work with the staff’ is peculiar and confusing to a number of such children if this phrase is interpreted to be an instruction and not a suggestion. This lack of doing what is suggested may be seen by staff as passive noncompliance whereas it may reflect the need for such children to be given clearer and more directed information, and the time to process such information.

All children should be managed effectively with the lowest level of force used, if required. There are daily many, many instances of staff pre-empting potential situations which could otherwise have led to restraint and the use of force.

Data about the impact of drawing PAVA, and if it is subsequently deployed in the adult estate, could be helpful to look at the deterrent impact of PAVA. Caution has to be applied when interpreting these results to the setting of the Children’s Secure estate as a child’s emotional and functional processing development throughout adolescence differs to how the mature adult brain works.
This area would be better described by the clinical psychology services but it is important to recognise the developmental phases of childhood, (eg noting that executive functioning may only be reached in the mid-twenties) as essential considerations regarding managing children, with or without having neurodiversity, ASD, ADHD and other conditions of note.

*Developmental affects, cancer mutagenesis,*

From the Committee on Toxicity, Mutagenicity and Cancer of chemicals in food, consumer products and the environment meeting in April 2002, (cot.food.gov.uk/sites/default/files/cot/cotstatementcspava0604.pdf)

they reported the following in 2006:

'ii. Animal model data and experience in use do not give rise to concerns regarding long-term harm to the skin and eyes arising from irritant effects. No conclusions can be drawn from the one available animal study to investigate skin sensitisation but experience in use, including in human medicines for topical application, indicates that PAVA is not a skin sensitising agent.

iii. There are no concerns regarding the mutagenicity of PAVA. PAVA gave a positive result in one of the three in-vitro mutagenicity tests carried out indicating that it could have mutagenic potential and negative results from an unscheduled DNA synthesis study and a bone marrow micronucleus test.

iv. There are no concerns regarding developmental toxicity. PAVA had low toxicity by the oral route, with no significant effects being seen in the maternal animals at doses up to 1000 mg/kg/day. The only effect seen in the developing offspring at this dose level was a small reduction in fetal weight. There was no evidence of any malformations, skeletal anomalies, or any other adverse effects at this dose level. The NOAEL for effects on the offspring was 500 mg/kg/day, about 4 orders of magnitude above the expected exposure level arising form the use of the spray.

v. The data from inhalation studies in volunteers, including those with mild asthma, indicate that there are unlikely to be any adverse respiratory effects in healthy individuals. It is possible that respiratory effects may occur in asthmatics, particularly since effects were observed in asthmatic volunteers at 0.1% PAVA, which is lower than the 0.3% used in the spray, and given the increased stress likely when the spray is used.

vi. The available information, both from the toxicity data in experimental studies and experience in use, indicates that the low exposures arising from the use of PAVA incapacitant spray would not be expected to be associated with any significant adverse health effects. The Committee recommended continuation of the monitoring of experience-in-use.'

The eye continues to change over time but from the evidence above given by the Committee of Food there would seem to no impact on animal models on its use.

**Conclusion**

Ultimately, there is a balance between using the minimal amount of force and the need to ensure the safety of other children and staff in violent situations. It may lead to a change in the relationship between staff and children if PAVA is used as this is a very high level of force, that incapacitates, causes pain and burning sensation. This is a speculative point, but research is needed to ensure that the rehabilitative circumstances for children are not altered by the introduction of PAVA and that staff child/children interactions are not affected.

It is important to note that the principles of MMPR may be undermined should there be easy recourse to the use of PAVA rather than focussing on behavioural management to deal with the situation.

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Independent Medical Advisor

APPENDIX 1

POLICE METROPOLITIAN DATA OVER 2 YEARS – JUNE 2021 until MAY 2023

https://capture.dropbox.com/x87GfMmx5kHS4HII

From an FIOA request to the Metropolitan Police Service, the following data were found, listed on the website above.

Irritant spray has been used 20 times whilst having been drawn 32 times in 2 years (I am presuming that these data are mutually exclusive).

Their use of PAVA is in a very different context to the use in the Secure Establishments but indicates that irritant sprays do not appear to have been used frequently in maintaining public order. There may be many mitigating circumstances which might be useful to understand e.g. who carries PAVA and the associated standing operational procedures for its use.