Managing the Risk from Children’s Travel Cups

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Introduction:

UK national newspapers have reported cases of children (and adults) who have got their tongue trapped in a Disney travel mug lid, causing extreme distress to the patients, their parents and Emergency Department staff. Potential risks include oral endotracheal intubation necessitating emergency tracheostomy to secure the airway, tongue necrosis and dental trauma. Although Disney have withdrawn their original mug from the global market, the same dangers can occur with other internationally available brands. Our aim was to design, test and present an alternative lid.

Methods and Materials:

We designed an alternative lid to fit onto the original Disney mug; our addition of two parallel bars prevented tongue protrusion into the lid. Prototypes of the original and new lids were 3D printed for testing. A tongue substitute was developed and a representative 0.2 bar suction force was generated. The bottle was mounted in a material test machine, attached to the load cell fixture. 4 samples each for the existing and new design were tested. The data were analysed by a custom Matlab script to extract the maximum force required to remove the tongues from the cup.

Results:

The new design resulted in a significant (p=0.0286, Mann Whitney U) reduction in pullout force. For the existing design the median pullout force was 4.64 Newtons (N) (minimum 3.86 N, maximum 4.91 N), whilst it was 2.37 N (minimum 2.20 N, maximum 2.53 N) for the new design. Trauma to the materials used with the original lid design was evident but not observed with our design.

Conclusion:

Our lid appears to offer a safer design that can avoid injuries. However, absolute safety remains unproved, as testing did not account for other body parts which may get trapped in the lid, nor did we test a range of tongue substitute sizes, and laboratory testing only was completed.
What this paper adds

What is already known:
- Reports in UK national newspapers of children and adults getting their tongue stuck in travel mug lids has resulted in Disney’s withdrawal that design from the global market. However, similarly designed cups remain on the market.
- These events cause significant distress to the patient/parents/ED staff and clinical teams have struggled in deciding how to safely manage this.

What this study adds:
- We designed a new lid prototype which avoids tongue trapping and associated injury to the user is prevented by the addition of two parallel bars in the lid opening.
- This study has been conducted in a laboratory and not in a real-world scenario, but has universal applicability in design. Further testing could use different tongue sizes or other body parts that might get caught, such as a child’s finger.
Introduction:

In recent years there have been cases reported by national newspapers and in the British Dental Journal, involving children who got their tongue trapped in the lid of a Disney travel cup (Figure 1), causing them to present to their local Emergency Departments. [1, 2] A story of such a case was broadcast by the BBC, resulting in Disney’s discontinuation of the product and the design’s subsequent withdrawal from the global market. [1] Similar products belonging to other internationally available brands have also resulted in similar concerning issues, indicating this may be an on-going problem.

Our experience was of a young boy who presented to the Emergency Department (ED), unable to remove his tongue from the lid of this travel cup (Figure 2). The mechanics of this specific design of lid prevented retraction of the protruded tongue; the vacuum that was then formed within the cup resulted in swelling of the highly vascular tongue muscle. The child and his parents had initially attended their local minor injuries unit and were advised to attend the local Emergency Department. The lid had been detached from the cup and clinical examination revealed tongue swelling and an intact dentition. The patient was understandably distressed. Attempts were made by the Oral and Maxillofacial Surgery (OMFS) dental core trainee to section the lid using a Mercian surgical hand-piece but this was unsuccessful as the bur struggled to cut through the volume of plastic. This led to concerns that the plastic would resultanty become hot and this technique was abandoned. Subsequent concerns regarding the difficulty to intubate, if required, and the risk of tongue necrosis prompted the on-call OMFS consultant to cut the lid using a ring cutter. Patient compliance was adequate to facilitate this, however, a younger or more distressed child may have found this too traumatic to tolerate. Although the tongue was painful and swollen following the lid removal, there were no obvious lacerations or other traumatic injuries.

Our findings and actions were mirrored by colleagues elsewhere in the UK, who have experienced this complication from the same design and brand of travel cup. In response to this safety concern, we set out to design and test a safer version of a child’s travel cup.

Methodology:
A Disney travel cup, of the same design as in the case detailed above, was three-dimensionally (3D) scanned (Romer Arm CMS108, Hexagon Manufacturing Intelligence, ROMER Division, Oceanside, CA, USA). From the scan data, a computer aided design (CAD) model of the original lid (i.e existing design) was constructed (Ansys SpaceClaim, Ansys Inc., Canonsburg, PA, USA). Based on this CAD model, an alternative lid (i.e new design) for the travel cup was designed; this fitted onto the original Disney mug but featured the addition of two small parallel bars in the lid opening. These bars prevented tongue protrusion into the cup and incorporated two small (1.0 mm diameter) holes either side of the spout (Figure 3). A base, incorporating a connection to a suction pump, was also designed such that the original lid and the alternative lid would fit with an airtight seal. The three components (original lid, alternative lid and base) were 3D printed in ABS plastic (UP Box+, TierTime Technology Co. Ltd, Beijing, China) for testing. Although not well documented in literature, a representative oral suction force was estimated (based on experiments) to be 0.2 bar; during testing this needed to be overcome to allow withdrawal of the tongue substitute material from the lids.

While maximum respiratory pressures at the mouth have been measured in numerous subjects, less data exists to characterise maximum pressures, as they vary with lung
volume. [3] To account for the fact that the tongue could be forced into the cup we used a ‘worst-case’ value of 20kPa. This was verified experimentally in the University laboratory testing but not specifically recorded.

A tongue substitute material (Figure 4) was developed from gelatine (dissolved at 1:1 ratio in water, poured into a mould and left to set for 4 hours at 4°C) to replicate the elastic properties of human tongue muscle. Eight sample tongue substitutes were made. A previous study found an overall mean of Young’s modulus to be 4.8±1.73 kPa for human tongues [4]. This is in the range expected for gelatine at a concentration of approximately 5-6% [5]. The gelatine formula used in this study was a commercial food formula (Hartley’s, Histon Sweet Spreads Limited, UK) and is likely to have a gelatine content of approximately 10-12%, prior to dilution (Gelatin Manufacturers Institute of America-Gelatin Handbook). Therefore, dissolving the gelatine in a ratio of 1:1 with water produced the required concentration and elasticity.

The base of the bottle was mounted in a material test machine, attached rigidly to the load cell fixture (Instron 5965, fitted with 50 N load cell, Bluehills v2 software, Instron Ltd, High Wycombe, UK). The lids were attached to the base in turn, then 0.2 bar suction force was applied using an airpump. The tongue substitutes were inserted, narrow end first, into the spout openings. The load required to subsequently remove them was recorded at 10 Hz. This was repeated four times for each type of lid.

Test data were analysed by a custom Matlab script, to extract the maximum force required to remove the tongues from the cup (Matlab R2019, The MathWorks Inc., Natick, MA, USA). The peak values of extraction force for the original and new lid designs were compared using Mann-Whitney U test (Matlab).

Results:
There was significantly (p=0.0286) large decrease in the required pullout force for the new design compared to the existing design. For the existing design the median pullout force was 4.64 Newtons (N): minimum 3.86 N, maximum 4.91 N. For the new design the median pullout force was 2.37 N: minimum 2.20 N, maximum 2.53 N (Figure 5). Trauma to the tongue substitute material tested with the original lid design was evident, (Figure 6) but was not observed with our new design.

Discussion:

The complication of tonguuges being trapped in travel mug lids has only been infrequently reported in the medical literature. Published cases have involved metal, glass or plastic bottles and have been reported in both adult and paediatric populations.[1, 2, 3] This highlights the potential for an increase in similar cases, as use of reusable travel mugs, drinks cups or bottles is prolific and almost universal.

Moreover, tongue necrosis resulting from oropharyngeal hardware, for neuro-monitoring purposes, has been reported in the literature.[6] Lingual infarction was due to a pressure injury from a laryngeal mask airway placed over an endotracheal tube to facilitate cranial nerve IX monitoring and resulted in the need for tongue debridement.[6] Although there have been no reports of tongue necrosis from entrapment in mug lids, the vacuum formed within the bottle could cause tongue odema, most likely through venous obstruction and strangulation. The vacuum in the bottle can be released by unscrewing the lid and detaching it from the bottle. However, tongue retraction from the lid is likely to be very difficult at this point due to the swelling already present.
Our findings demonstrate a reduction in the force required to extract the tongue substitute from the new design lid when compared to the original design. While there was obvious trauma to the tongue substitute material with the original design no damage was observed to the tongue substitute when testing with the new lid design. There was also no damage or breakage noted to the two bars in the new lid design. This demonstrates that the two parallel bars successfully prevent tongue protrusion into the lid and therefore injury to user.

Although the focus of this study was not on removal of the lid from the tongue, in our experience lid removal with a Mercian surgical drill system was unsuccessful and posed risks of burns as the the plastic lid may become hot; this would also be the case for metal bottles. Successful removal was achieved using a ring-cutter. In our case, the airway was secure and the priority was therefore removal of the mug lid from the tongue.

Limitations:
We have tested our new design with respect to the human tongue but it should be noted that absolute safety remains unproved, as testing did not involve human subjects and was not extended to, for example, confirmation that a child could not trap their little finger in the small holes in the lid. There are potentially other risks to the user in standard designs, including dental trauma: the dentition, particularly the primary dentition, may be at risk of avulsion, luxation or subluxation injuries or hard tissue fractures. Our design did not address this aspect of safety but this should be noted by treating clinicians as a potentially likely injury. We also recognise that a further, follow-on study could be undertaken on consideration that other body parts may become trapped.

A greater degree of validity may have been achieved through the use of different tongue sizes in testing; we used one standardised size. Our testing was entirely laboratory-based but further studies could include observation of a group of children using and playing with the cup. Ethical approval would be required for this.

The principle of our design change has universal applicability and high feasibility given simplicity. We currently do not have plans for further testing but are continuing to attempt to pitch our new design to Disney.

Conclusions:
The standard lid design for travel mugs has the potential to cause injuries in children. Given the proliferation of travel mugs or other bottles with similar designs, which are internationally available, a new design is necessary. Our design is likely to reduce the frequency of injuries but needs to be tested in a real-world scenario.
References:
Figure legend:

Figure 1: Original Disney Mug. Rights to this mug design are owned by The Walt Disney Company. Photograph taken by the authors of an original mug they had purchased.
Figure 2. Young boy with his tongue stuck in the lid.
Figure 3. The original lid (turquoise), the 3D printed original lid (green) and the new design (white).
Figure 4. Tongue substitute materials
Figure 5. Box plots showing difference in pullout force (N) between the existing and new lid designs.
Figure 6. Torn tongue substitute, when tested with original lid.