ONLINE SUPPLEMENT: Effectiveness of approaches to choking due to foreign body airway obstruction- a physiological study.

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CASE REPORTS

Introduction

The National Safety Council USA [1] reports that foreign body airway obstruction (FBAO) is the fourth leading cause of unintentional injury death, with 4864 reported deaths in 2013. Since two of the reports of near-fatal choking below occurred in the context of alcohol consumption and one where the person was distracted while eating we encourage readers to eat and drink safely and in moderation.

Case 1

Case 1 was in a party of 20, enjoying a meal of fonduebourguignonne (involving beef segments with a size approximating the tracheal diameter) with liberal local wine. Suddenly he became aware of a member of the party further down the table standing up, gesticulating, clearly unable to speak and being hit on the back by his neighbour. The signs seemed pathognomic of occlusive apnoea due to obstructed airway. He went rapidly to the subject, who by this time was looking decidedly grey. He performed 2 abdominal thrusts without success and then a third time with the maximum force he could achieve. To his relief a lump of meat shot out of the subject's mouth. Both physician and subject took some deep breaths and dinner resumed for all.

Case 2

Case 2 was writing a research grant in a caravan in his garden as builders were renovating his house. He was alone, aside from his dog. Taking a second bite from a steak sandwich he became acutely aware of a bolus of steak stuck firmly in his gullet. He could not breathe in or out, or make a sound. The meat was beyond the grasp of his fingers and there were no useful implements to hand.

He realised the situation was precarious and ran to seek help from the builders. Rapidly developing a sensation of impending doom, it became apparent he would not reach the builders, and even if he did, they were unlikely to do anything other than call an ambulance which would arrive too late. In this immediately life-threatening situation he performed the Heimlich manoeuvre on himself. The first attempt was unsuccessful. The second time he applied all his strength: the lump of steak dislodged and flew through the air. His faithful dog jumped up and ate the meat before it hit the ground.

Case 3

Physician Case 3 was enjoying steak in a restaurant with friends. He reports: "I suddenly realised I was shifting virtually no air. I swallowed again and again, but a piece of steak in my upper airway was going nowhere. The urge to inspire as hard as possible to overcome the resistance was almost overwhelming, but through rising panic I realised that a strong inspiratory effort would almost inevitably lead to complete impaction. Breaking the golden rule, I left the table and hurried the few steps into the street. With almost no air in the lungs, I put my fists in my epigastrium, and jerked them up hard as I simultaneously doubled over and tried to cough. With a satisfying splat the bolus hit the pavement. An elegant pair of Jimmy Choo's swerved past it, and through streaming eyes I looked up to see their appalled owner. "I was choking, not vomiting", I gasped – but her look of disdain said it all."

Summary

The case reports demonstrate that abdominal thrusts, either self-administered or performed by a first aider can be effective in the expulsion of food obstructing the airway, and can thus save lives.

In each case the obstruction was complete, and unconsciousness followed by death would surely have occurred within minutes. But for the application of the Heimlich manoeuvre, the country would be short of two respiratory physicians and one senior diplomat. There were no short or long term sequelae in our 3 cases and all 3 subjects confirm in the strongest terms that they are pleased to be alive.

DETAILED METHODS

Participant selection

Adult physiology researchers with no significant comorbidity or adverse medical history, who had experience swallowing oesophageal and gastric balloon catheters, were invited to participate. Subjects provided written informed consent prior to enrolment in the study, which was approved by the Imperial College Joint Research Office and the Health Research Authority (IRAS 200606) and conducted in line with the principles of Declaration of Helsinki.

Procedures

Participants swallowed oesophageal and gastric balloon catheters (Carefusion: Berlin, Germany), length 86 cm, balloon length 9.5 cm. Pressures were measured by Validyne MP45-1 differential pressure transducers, range 150 cmH20 and amplified by carrier amplifiers (Validyne Co. Northridge California, USA). Calibration between each study was completed with a Universal Pressure Meter (BIO-TEK Instruments Inc. USA). Signals were passed into PowerLab software (AD Instruments, Oxford, UK) and sampled at 100Hz.

Manoeuvres

Participants underwent expulsive manoeuvres which were performed in random order by two experienced physiology researchers holding Life Support Certification or self-administered (see Box E1). Manoeuvres were performed after exhalation to the end of a normal breath (at functional residual capacity, FRC) with mouth and glottis closed and a nose clip in situ.

One participant (NSH) underwent additional manoeuvres; back blows as per basic life support guidance [2], supine chest compressions with hand positioning as for CPR [2], starting with medium force and gradually increasing force downwards and finally supine abdominal compressions, hand position as described for standard positioning for abdominal thrusts, initially with medium force and gradually increasing.

Box E1: Description of Manoeuvres

Circumferential "horizontal" Abdominal Thrust
The operator stands behind the participant, grasps their fists together and places thumb side of the fist over the fleshy part of the abdomen above the navel. The operator pulls sharply backwards starting with medium force and progressively increasing force, until the maximum pressure that the subject feels is acceptable is achieved.

Heimlich Manoeuvre
The same procedure but with an upwards direction of force.

Auto "upthrust" Abdominal Thrust
The participant positions their own hands in the standard position for the abdominal manoeuvre and performs thrusts increasing to the maximal force they can tolerate.

Chair Thrust
The participant positions themselves above a high backed chair, with the chair back positioned below the upper half of the abdomen, below the ribcage. Using, gravity, bodyweight and arms for additional force the participant allows the back of the chair to thrust up into their abdomen (see Figure 1).

Volitional maximal cough and sniff pressures
The participant performed repeated maximal volitional cough and sniff manoeuvres.

Statistical Analysis

Data were analysed using Graph-Pad Prism Version 5.0 for Windows (Graph-Pad Software, San Diego, California, USA). Mann-Whitney test was used to compare the maximum oesophageal and gastric pressures generated by the various manoeuvres. For the circumferential "horizontal" abdominal thrust and for the "upthrust" Heimlich manoeuvre each subject had the manoeuvre performed by two operators, which were treated as independent data points. A p-value of <0.05 was considered significant. Data presented as median (± SD) unless otherwise stated.

RESULTS

Four male subjects took part in the study which was performed in July 2016. Baseline characteristics median (range): age 56.5 years (46 to 74), weight 77.0 kg (73 to 87.7), height 172.5 cm (172 to 183), BMI 25.9 kg/m^2 (25 to 26).

Pressures generated by manoeuvres

Maximum peak oesophageal (Poes) and gastric (Pgas) pressures did not differ significantly between the different abdominal thrusts when performed by the experimenters or by the subjects on themselves (Figure 2 and Table E1). Peak oesophageal pressure generated by the upthrust Heimlich manoeuvre was 57 ±17 cmH2O and 53 ±11 for the circumferential abdominal thrust (p=0.721). However the pressure generated by the chair thrust was significantly higher than both, with Poes 115 ± 27 cmH_2O (p=0.008when compared to Heimlich). Peak oesophageal pressures are

outlined in table E1. The outlier auto-abdominal thrust data point in Figure 2B corresponds to the participant (MH) who had performed an abdominal thrust on himself described in case 2.

In one participant three further manoeuvres were performed. The Poes generated by back slaps (7 cmH_2O) and chest compressions when supine (position taken as for CPR) (42 cmH_2O) were lower than both the Heimlich manoeuvre (64 cmH_2O) and cough (179 cmH_2O) in that subject. However abdominal compressions when supine generated 86 cmH_2O, comparable to abdominal thrusts when upright.

Reviewing the data after four subjects the conclusion was that studying further individuals would be unlikely to alter the findings.

Table E1.

Median Peak Pressure Oesophageal (Pgas) and Gastric (Poes) and Range for each Manoeuvre

Manoeuvre	Peak Gastric Pressure	Range	Peak Oesophageal Pressure	Range
Heimlich	112 (±18.5)	88 – 139	57 (±17)	39 – 88
Circumferential Abdominal Thrust	115 (±19)	87- 138	53 (±11)	33 – 68
Auto Abdominal Thrust	100 (±52	83 – 199	74 (±29)	22- 85
Chair Thrust	238 (±34)	179 – 250	115 (±27)	76 – 138
Cough	207 (±29)	185 – 250	189 (±33)	179 – 250

Values are in cmH_2O and Median (±SD)

REFERENCES

1. Choking 2016 [Available from: http://www.nsc.org/learn/safety-knowledge/Pages/safety-at-home-choking.aspx.
2. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 2. Adult basic life support and automated external defibrillation. *Resuscitation* 2015;95:81-99. doi: 10.1016/j.resuscitation.2015.07.015 [published Online First: 2015/10/20]

FIGURE LEGENDS

Figure E1 (Online supplementary video) – one of the authors performs a chair thrust on themselves.