A 3D-printable Laryngoscope Blade for Intubation of Rats

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Keywords:

Intubation, rodents, rats, laryngoscope, 3D-printing

Abstract

Endotracheal intubation of rats is a common technique best undertaken with a laryngoscopic blade as this allows intubation under direct vision, and avoids accidental intubation of the oesophagus. However, published designs for rats are not commercially available. 3D printers have recently become widely available and allow practical and reliable production of small plastic items, once the design has been created. Here we present a design for a laryngoscopic blade using a 3D printer and polyactide filament so that any experimenter with access to a 3D printer would be able to fabricate the part. We successfully intubated 35 rats using this technique without any oesophageal intubation.

Endotracheal intubation in rats is commonly needed to secure the airway in bio-medical experiments that require deep anaesthesia with or without neuromuscular blocking agents. Alternatively, a tracheotomy can be performed, if the experiment is terminal, but should not be used in recovery experiments as wound infections, pneumonia and tracheal stenosis can occur. Endotracheal intubation in rodents poses a challenge to the experimenter due to the anatomy of their pharynx, with its large tongue, small larynx and trachea and a relatively long distance from the incisor teeth to the trachea. Previously published methods for intubating rodents include blind intubation [1], paediatric laryngoscopes [2], spatulas [3], modified nasal specula [4], otoscopes [5] and transillumination [6,7]. Designs of laryngoscopes specifically for rats have been presented [8,9]; however, most of these are not commercially available and require the experimenter to manufacture the item themselves. 3D printing is a process of making a three-dimensional solid object from a digital model. This is achieved by an additive process; where successive layers of material are laid down to form the desired shape. In the process used here the 3D printer deposited melted plastic in layers to form the laryngoscope. We used uncolored polyactide (PLA) filament for our design to avoid possible toxicity from added coloring. PLA is a biocompatible transparent plastic produced from corn or dextrose which generally recognized as safe for food contact[10] and is used in the medical field for suture material[11], drug delivery[12] and as an implantable scaffolding in regenerative medicine[11,13]. Prices for tabletop 3D printers have recently dropped significantly and are now widely available in universities, for personal use or as commercial printing services. Here we share our design of a laryngoscope blade for endotracheal intubation in the rat which allows the experimenter to print the laryngoscope blade using a 3D printer. The files are available for download at the Thingiverse website (http://www.thingiverse.com/thing:148315). The laryngoscope can be easily fitted with a fibre-optic light source, but the authors found it sufficient to use an LED headlight for illumination. We used a tilt table to ease intubation, of which several designs have been described in the past (for example [14]). We designed our tilt table to support adult rats (300-400 g) and constructed it from cut-to-size sheets of acrylic (see figure 2).

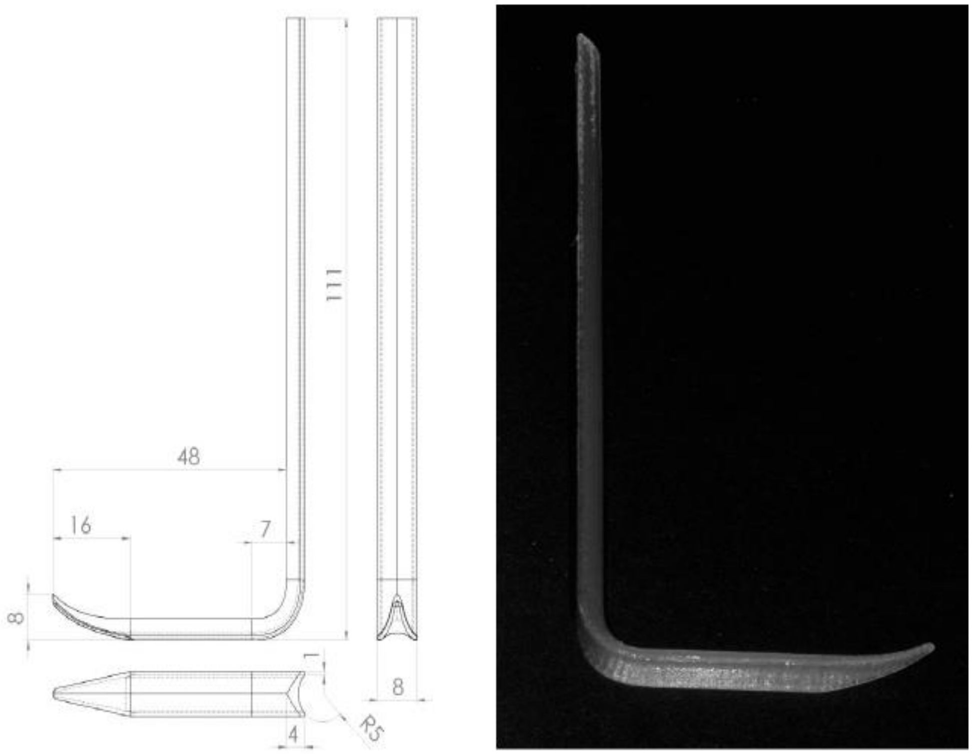

Figure 1

Figure 2

Methods

Animals

All experiments followed the guidelines of the Animals (Scientific Procedures) Act, 1986 and its associated codes of practice, and the European Directive 2010/63/EU on the protection of animals used for scientific purposes. All animal work reported here was conducted as part of different studies, which were approved under UK Home Office regulations. Thirty-five female Sprague-Dawley rats aged 5-8 months, weighing 300-400 g, were intubated using the laryngoscope. They were all used for an experiment in which neuronal activity was imaged using electric impedance tomography for which electrodes were implanted subdurally onto their brain. The study protocol included induction and imaging of epileptic seizures under anaesthesia. They were obtained from Biological Services, University College London, which bred them on site. They were kept in a room with 12 hour dark/artificial light cycle with 18-20 air exchanges/hour, and had access to food and water ad libitum.

Design and production of the laryngoscope blade

The laryngoscope blade is 8 mm wide and has an angled shaft of 16 mm length. The total length of the blade is 48 mm and the handle is 111 mm long (see figure 1). The laryngoscope was printed using a Makerbot Replicator 2 3D-printer with uncolored polylactide (PLA) filament (both Makerbot Industries LLC, NY, USA). Printing was accomplished in 10 minutes; the material cost for each laryngoscope was approximately 10 cent (USD). The laryngoscope was inspected for any sharp edges and these were rounded with sanding paper where required.

Chemical Resistance of the laryngoscope blade

We tested the chemical resistance of PLA in ethanol (AnalR Normapur, VWR International, France) for 12 hours and in sodium hypochlorite (Sigma Aldrich Company Ltd, UK) 2.3% (equals 1/2.5 of 5.25% bleach) for 20 min for n = 5 samples.

Intubation procedure

The rats were induced in an induction box using 5% isoflurane in 100% oxygen. Once unconscious they were moved onto a nose cone and, once their breathing had slowed to ~30 breaths per minute, were moved into supine position on a tilt table (figure 2). A wire loop was hooked under the superior incisors of the rat which was then attached to the top end of the tilt table using Velcro pads. The table was then tilted and the tongue was grasped with a non-toothed forceps and pulled to one side of the incisor teeth. The laryngoscope was introduced with the acute angle rostral, and the vocal cords were visualised by pointing the angled tip slightly upwards; lighting was provided with a LED headlight. It was only necessary to introduce the first 2 cm or so of the laryngoscope presented here; the remaining shaft was used for grasping and manipulation. The pharynx was then sprayed with lidocaine hydrochloride (Intubeaze, Dechra Pharmaceuticals, UK) to desensitize the vocal cords and prevent laryngospasm. A soft stainless steel wire, which had been removed from a 14 G human central venous catheter set (Leader-Cath, Laboratoires pharmaceutiques Vygon, France), was passed through a 14 G straight intravenous cannula measuring 51 mm in length (Abbocath-T, Hospira, Ireland). The wire was introduced through the vocal cords into the trachea under vision and the cannula was pushed over the guide wire. The wire was subsequently removed. Endotracheal placement was confirmed by condensation on a dental mirror held in close proximity of the tracheal tube. Ventilation was started using a Harvard Apparatus Inspira Ventilator (Harvard Apparatus Ltd., UK).

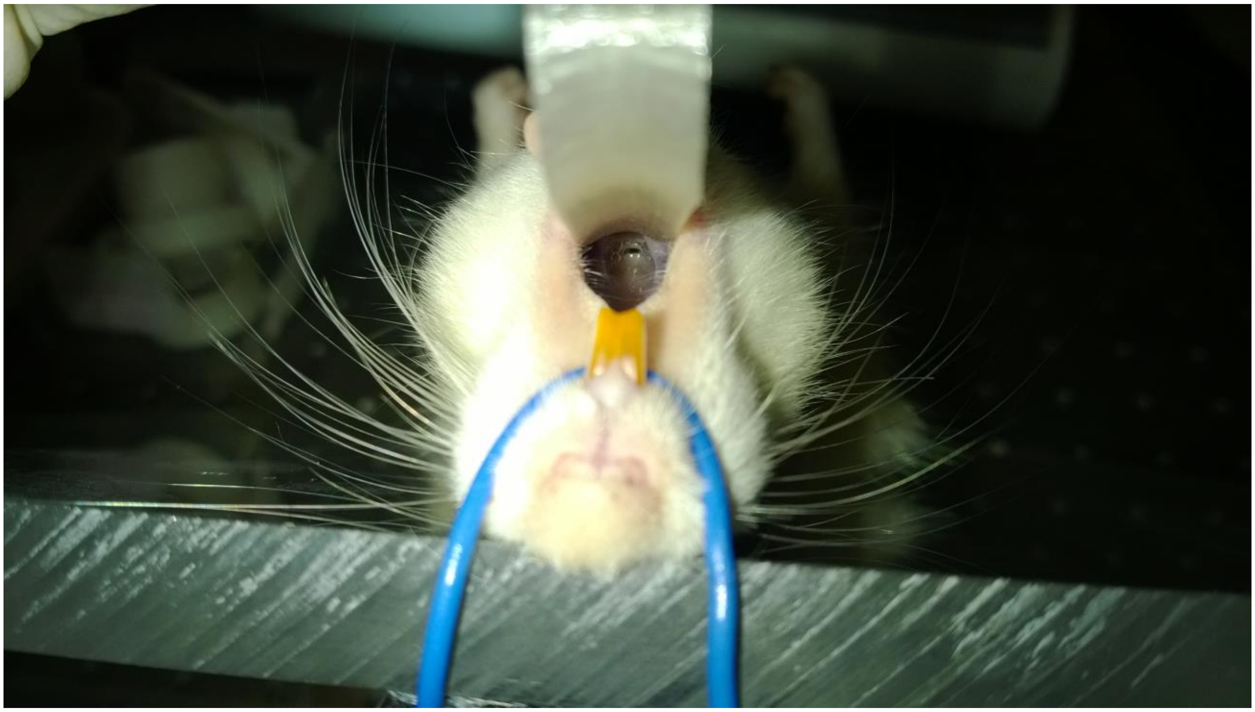

Figure 3

Results

It was possible to perform the intubation in approximately 3 min in all rats. No oesophageal intubations occurred in any of the 35 intubations, no other ventilatory difficulties occurred in the recordings lasting between 6-10 hours. A single printed laryngoscope could be used in all the intubations. No ventilatory difficulties occurred during the experiments lasting up to 10 hours following the intubation. The intubation allowed stable anaesthesia for craniotomy and electrode placement, as well as subsequent imaging of epileptic seizures. . No obvious damage to the plastic occurred after 12 hours of soaking the item in ethanol or 20 minutes in 2.3% sodium hypochlorite.

Discussion

The laryngoscope presented here is stable enough to be used multiple times and withstood disinfection with ethanol and sodium hypochlorite. Alternatively, sterilization of PLA based implants using ethylene dioxide has been described previously[11]. 3D printing allows researchers to design and produce small items according to their individual need at a low cost and with a quick turn-over, the advantage is multiplied if the design is subsequently made available to the community. Multiple free software packages to design three-dimensional objects, together with tutorials are available online. 3D printers have become increasingly available at universities, especially in their engineering departments, but also as commercial print services. This design of a laryngoscope is simple and practical to implement given access to such a system. It is presented in the hope that it could help researchers save time and funds when preparing for studies which require laryngeal intubation in the rat. We hope that more biomedical researchers share the design of useful, commonly needed items with the community.

Funding acknowledgement:

This work was supported by the Wellcome Trust (Grant No WT094822MA) and the Medical Research Council (Grant No MR/K00767X/1).

Declaration of conflicting interest

The Authors declare that there is no conflict of interest.

List of figures

Figure 2: Tilt table, all measurements in millimeters; the table presented here was constructed from cut-size sheets of acrylic of 1 cm thickness. A wire loop was attached to the top end of the table to allow the rat to be kept in position by hooking the loop under its incisor teeth. The loop was fixed to the table with Velcro.

Figure 3: Photograph of a rat positioned on the tilt table with the laryngoscopic blade inserted.

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