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Cannot ventilate-cannot intubate an infant: Surgical tracheotomy or transtracheal cannula?

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Pediatric Anesthesia

Cannot ventilate-cannot intubate an infant: Surgical tracheotomy or transtracheal cannula?

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Cannot ventilate-cannot intubate an infant: Surgical tracheotomy or transtracheal cannula?

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Running head: Surgical tracheotomy or transtracheal cannula in infants?

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Summary

Background: An unanticipated difficult airway is very uncommon in infants.

The recommendations for managing the can't ventilate-can't intubate ('CVCI') situation in infants and small children are based on difficult airway algorithms for adults. These algorithms usually recommend placement of a transtracheal cannula or performing a surgical tracheotomy as a last resort. In this study we compared the success rate and time used for inserting a transtracheal cannula versus performing a modified surgical tracheotomy in a piglet model.

Methods: We used 10 three-weeks-old euthanized piglets, weighing eight kilograms each. Thirty physicians had a timed attempt of inserting a transtracheal cannula for jet ventilation. A maximum time of 120 sec was allowed. Ten physicians had a timed attempt of performing a modified surgical tracheotomy after a short introduction by an ENT surgeon. The allowed time for this procedure was 240 sec.

Results: Placement of the transtracheal cannula was successful for eight of 30 physicians. Median time for successful insertion was 68 sec. Surgical tracheotomy was successful for eight of 10 physicians. Median time for successful tracheotomy was 89 sec. There was a significantly higher success rate for surgical tracheotomy ($P=0.007$).

Conclusions: We found placement of a transtracheal cannula to be significantly less successful than the modified surgical tracheotomy in a piglet

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3 model. We question if placement of a transtracheal cannula should be
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5 recommended in infants in a can't ventilate-can't intubate situation.
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24 **Keywords:** difficult airway; animal model; airway algorithm; emergency
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26 tracheotomy; children; transtracheal cannula.
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Introduction

In healthy infants an unanticipated difficult airway is very uncommon. The horrifying situation in which ventilation, oxygenation, and intubation are impossible, is fortunately extremely rare and most anaesthetists will rarely - if ever - encounter this scenario. In this situation when all other means have failed, an invasive technique to ensure oxygenation must be considered. In adult airway algorithms, it is usually recommended to do a needle or surgical cricothyroidotomy, but in infants or small children the recommendations are less clear (1, 2). Only one national recommendation exists for children and the last step in the 'can't ventilate-can't intubate' situation ('CVC1') is "a rapid tracheal access or transtracheal jet ventilation" (3). The technique to achieve this is not specified.

As the situation is extremely rare, no comparative studies exist and probably very few anaesthetists have any experience in invasive techniques that allow emergency airway access in small children thus a suitable training model of this situation is **both necessary and** difficult to make. Practicing on a manikin may help in decision-making and team work, but it is far from reality to palpate and place a needle on a silicone manikin. An animal model will be more realistic, but only one infant model using kittens has been presented in the literature (4).

The aim of this study was to compare the success rate and time used for placing a transtracheal cannula versus performing a modified surgical tracheotomy in a piglet model.

Materials and methods

Piglets were chosen for the model as the authors have a broad experience in using pig necks as an adult model for practicing emergency airway access.

The airway of eight kilogram piglets have dimensions comparable to small children. When the piglets are placed on their backs, the trachea and larynx are identified as soft structures as in children.

Ten three-weeks-old piglets, weighing eight kilograms **were euthanized by a veterinarian.**

Thirty physicians who attended a difficult airway workshop, agreed to participate after being informed about the study.

The participants had prior to the workshop attended lectures on transtracheal jet ventilation and paediatric emergency tracheotomy. During the workshop an ENT surgeon introduced the participants to the tracheotomy technique and the equipment to be used.

For the transtracheal cannula placement the technique recommended by The European Resuscitation Council guidelines was used (5). A water filled 10 ml syringe with a standard 16 or 18 GA intravenous cannula (Venflon™ Pro) attached was used to puncture the trachea just inferior to the cricoid cartilage percutaneously at an angle of 45⁰ caudally (Figure 1). After verification of correct position by air aspiration, the needle was removed and the cannula was connected via a three-way stopcock to a high-pressure oxygen source. Inspiration or “jetting” was performed by occluding the free limb of the

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3 stopcock by a finger causing oxygen to be insufflated via the cannula for one
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5 second followed by four sec for “expiration” (Figure 2).
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10 The participants were timed from the start of palpation on the piglets’ neck.
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12 Jet ventilation was started when the participant was convinced that the
13
14 cannula was placed in the trachea. Verification of cannula placement was
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16 performed clinically by watching movement of the thorax. If in doubt, the
17
18 airflow was increased and/or the escape of air prevented via the upper airway.
19
20 An attempt was considered a failure if a functioning cannula was not in place
21
22 within 120 sec from start, or if “jetting” was attempted with a non-functioning
23
24 cannula. The time limit was set to make it more “realistic”: If the trachea is not
25
26 cannulated **within two minutes of starting the procedure** the hypoxia will be
27
28 life-threatening. **In addition, injury to several adjacent structures would**
29
30 **likely have occurred, why it would be meaningless to pursue the same**
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32 **strategy.**
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41 For the modified surgical tracheotomy we selected tools readily available in
42
43 theatre. A scalpel, a pair of scissors with a sharp tip and three towel forceps
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45 (Figure 3). The larynx and proximal trachea were identified by palpation, and
46
47 a vertical incision was performed through the skin and subcutaneous tissue
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49 from the upper part of the larynx to the sternal notch. The strap muscles were
50
51 grasped with two towel forceps and separated in the midline giving access to
52
53 palpate and identify the trachea. Bleeding makes visual identification of the
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55 trachea more difficult and the participants were encouraged not to look for but
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57 to palpate the tracheal rings in order to indentify the trachea. The trachea was
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3 stabilised by grasping it from side to side with a towel forceps, and while the
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5 sharp tip of the scissors was inserted between two tracheal rings one to two
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7 cm distal to the larynx, the trachea was lifted anteriorly in order not to damage
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9 the posterior wall or resect the cartilage (Figure 4). With the scissors a vertical
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11 cut in the midline of the trachea in the distal direction was made, and the
12
13 endotracheal tube was inserted. Placement was verified by successful
14
15 ventilation of the lungs or by fibroscopy.
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20 A tracheotomy attempt was considered a failure if no endotracheal tube was
21
22 placed within 240 sec **since this procedure would result in a definitive**
23
24 **airway.** If more than four minutes are used for the emergency tracheotomy a
25
26 good outcome will be less likely. First all the participants, three per piglet, had
27
28 a timed attempt of placing a transtracheal cannula for jet ventilation. **Ten**
29
30 **randomly selected** participants subsequently had a timed attempt of doing a
31
32 modified surgical tracheotomy and inserting a cuffed endotracheal tube size
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34 3.5 mm ID.
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39 The participants were told about the maximum time allowed prior to the study.
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44 Before starting the procedure, in half of the piglets the tip of an Olympus Lf-2
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46 flexible fiberscope, connected to an Olympus CLE cold light source was
47
48 placed at the level of the vocal cords by means of direct laryngoscopy. In this
49
50 way the subglottic space and the trachea were observed during the entire
51
52 procedure. The observations obtained via the fiberscope were not available to
53
54 the person performing the transtracheal procedure nor to the person doing the
55
56 timing and clinical confirmation of the cannula placement.
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3 After the workshop the trachea of the piglets were transected just below the
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5 cricoid cartilage and the tracheal diameter was measured.
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10 *Statistics*

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12 Continuous data are reported with median and range, and proportions are
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14 reported with 95% confidence intervals.
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17 The primary end point was the time for obtaining access to the airway, either
18
19 by insertion of the transtracheal cannula or by performing surgical
20
21 tracheotomy. This was compared using the Mann-Whitney test as we
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23 considered the attempts to be independent. The secondary end point was the
24
25 success rate for the procedure. This was compared with Fisher's Exact test,
26
27 based on the assumption that the two procedures were independent.
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30 We illustrated the time and success using Kaplan-Meier statistics.
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33 A p-value less than 0.05 was considered significant.
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39 **Results**

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41 Introduction of the flexible scope allowed adequate visualization of the
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43 subglottic space and the trachea during the entire procedure in the five
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45 piglets, in which this was attempted.
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48 Placement of a transtracheal cannula was successful in eight of 30 (27%)
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50 attempts within 120 sec. **The median time of the eight successful**
51
52 **insertions was 68 sec (35-95 sec) until jet ventilation was established.**
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55 Visualization using the fiberscope was carried out in 14 of these 30 attempts.
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57 The examination revealed a discrepancy between the clinical verification of
58
59 the cannula placement and the actual placement in four of the 14 (29%)
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3 attempts. This included attempted jet ventilation despite paratracheal
4 placement, a kinked catheter, and also a correctly placed cannula, but no jet
5 ventilation because of uncertainty of the cannula placement.
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10 **A modified surgical tracheotomy was performed successfully in eight of 10**
11 **(80%) participants within 240 sec. The median time for successful insertion of**
12 **the endotracheal tube with this procedure was 89 sec (71-200 sec). The ten**
13 **participants performing a tracheotomy had a similar success rate of**
14 **transtracheal cannula placement as the other participants (two out of**
15 **10).**
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24 The successful placement of a transtracheal cannula tended to be faster
25 (P=0.08) (Table 1, Figure 5), **but the success rate for surgical**
26 **tracheotomy was significantly higher (P=0.007).**
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31 The fiberoptic examination was performed in five of the 10 attempts of
32 surgical tracheotomy and confirmed correct placement of the endotracheal
33 tube in all five cases. The tracheal diameter was eight mm (6-9mm)
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41 **Discussion**

42 We found that anaesthetists had significantly less success in placing a
43 transtracheal cannula within 120 sec than in performing a modified surgical
44 tracheotomy within 240 sec.
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50 In infants and small children the dimensions of the cricothyroid membrane are
51 small and the cricoid cartilage is narrow, which makes it difficult or impossible
52 to pass an endotracheal tube through the membrane without risk of fracturing
53 the cartilages of the larynx (6). This combined with the difficulty in identifying
54 the membrane in infants because of the short neck, the cephalad position of
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3 larynx, the softness of the cartilages, and the prominent hyoid bone, which is
4 easily mistaken for the thyroid cartilage, makes it unattractive to perform
5 cricothyroidotomy in small children (7).
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12 The alternatives left in a 'CVCI' situation are to perform an emergency
13 tracheotomy or insert a transtracheal cannula. **The tracheotomy is a**
14 **definitive airway, which can be used for ventilation, whereas the**
15 **transtracheal cannula only is a temporary measure, which makes it**
16 **possible to oxygenate the child with modified jet ventilation until**
17 **surgical expertise arrives to perform a tracheotomy. Despite this, since**
18 anaesthetists are very familiar with cannula techniques and not surgically
19 trained, the transtracheal cannula insertion will be the most appealing choice
20 to the majority of anaesthetists.
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36 In our study surprisingly many of the participants had difficulty inserting a
37 transtracheal cannula in the piglet model, despite the relative ease of
38 palpating the larynx and upper part of the trachea. Only 27% succeeded
39 within the time limit of 120 sec. In the 14 attempts assessed via the
40 endoscope we also noticed that the anaesthetist had difficulty determining
41 whether the cannula was in the tracheal lumen or not. In one case the
42 cannula was correctly placed but kinked and could not be used. **This could**
43 **probably have been avoided by using a more kink resistant device as for**
44 **instance the "Ravussin catheter"**. The success rate of transtracheal
45 cannula was low and there is a risk of serious complications such as air
46 embolism, extensive cervical emphysema, pneumothorax and
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3 pneumomediastinum, and damage to the oesophagus if jet ventilation is
4 attempted using a misplaced cannula.
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8 We found that a short introduction to a modified surgical tracheotomy proved
9 to be sufficient to make eight of 10 participants able to perform successfully
10 on the model within the predefined time limit. The median time for successful
11 tracheotomy was 89 sec. Although this is 21 sec more than for the successful
12 insertion of a transtracheal cannula, the success rate was three times higher.
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14 In addition, the tracheotomy is a secure airway, whereas the transtracheal
15 cannula is **only a temporary airway, which easily displaces and must be**
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25 **substituted urgently with another one.**
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29 The tools available were chosen to be as simple and few as possible to
30 simulate a realistic scenario. A scalpel is always readily available in theatre
31 and a pair of scissors and the towel forceps are standard equipment in our
32 anaesthetic trolley. We chose to make the tracheal incision with the scissors
33 instead of using the scalpel, to make it easier for a surgically untrained person
34 to control the size of the tracheal incision.
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46 This piglet model of course has limitations. It is not possible to create the
47 same extreme level of stress that a severely hypoxic child will cause. But the
48 stress will probably be equally disadvantageous in both procedures. As the
49 piglets were dead, there was no bleeding during the procedure. Bleeding must
50 be expected in a real situation and will add to the stress and make the
51 procedures more difficult. In order to compensate for this we encouraged the
52 participant not to depend on vision during identification of the trachea and
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3 instead palpate to find the tracheal rings. The strengths of this model are that
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5 the palpation for the landmarks and the sensations during cannulation and
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7 surgery are very realistic and much better than when using manikins. **The**
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9 **piglets size corresponds to an infant of 6 months to 3 years.**
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17 In adults a transtracheal cannula is a well-established way of keeping an
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19 acceptable oxygenation during a 'CVCI' situation until a more secure airway is
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21 established (8,9). This is probably the explanation for recommending this
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23 procedure as a last resort in the emergency airway management in infants
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25 and small children as well (6, 7) (10, 11).
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29 The evidence for this recommendation does nevertheless not exist. Only a
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31 few papers, including one case report and one small series of elective
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33 percutaneous transtracheal jet ventilation, **using the specially designed**
34
35 **"Ravussin catheter"**, in children have been published (13, 14). The
36
37 transtracheal cannulas were placed during controlled circumstances under
38
39 direct endoscopic visual guidance in a well-oxygenated child. Despite this,
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41 serious complications occurred, including bilateral pneumothorax. This
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43 situation is very different from the chaotic situation that rules at the time point,
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45 when the anaesthetist finally as the last resort decides to attempt placing a
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47 transtracheal cannula in a severely hypoxic child.
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55 In the literature we have not found any studies documenting success or risks
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57 associated with needle cricothyroidotomy or transtracheal needle access in a
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59 'CVCI' situation in infants. Only one case with a successful placement of a
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3 transtracheal cannula in a six year old, 20 kg Treacher Collins girl was found.
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5 In this case the cannula was placed via a pre-existing tracheal fistula (15).
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11 Currently the recommendations are based on expert's opinion and reviews of
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13 articles focused on adult airway management (8) (10). Weiss et al (16)
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15 recently proposed an algorithm for the management of the unexpected difficult
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17 paediatric airway based on the Difficult Airway Society's (DAS)
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19 recommendations for adults (1). As their rescue technique in the 'CVC1'
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21 situation they reserve cannula cricothyroidotomy for children older than eight,
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23 but they recommend surgical cricothyroidotomy in patients of all ages.
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30 The 'CVC1' situation in a small child without anticipated difficult airway is
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32 extremely rare. As with other rare situations, ie malignant hyperthermia, it is
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34 important to be prepared and practice the situation on models or in simulators
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36 to improve the chance of survival of the patient. Not only the technical skills
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38 but also decision making should be trained.
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44 Thorough preoperative assessment, clinical education, simulator training,
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46 and implementation of national society recommendations are all important in
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48 order to reduce the occurrence of a failed airway (16). We think this should be
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50 combined with further development of an animal model for training and
51
52 practicing surgical emergency airway access in infants and children. The set-
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54 up described by Heard et al. (8) seems ideal, but the use of live animals is
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56 very demanding and costly and therefore probably not an option in most
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58 departments.
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3 We cannot draw any firm conclusions from this small study, but it may
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5 stimulate to some thoughts and more studies, involving animal models, on
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7 emergency airways in small children. We found the placement of a
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9 transtracheal needle to be more difficult and less successful than the modified
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11 surgical tracheotomy in a piglet model. We question if placement of a
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13 transtracheal cannula should be recommended in infants in a can't ventilate-
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15 can't intubate situation.
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For Peer Review

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Transtracheal cannula placement.
215x269mm (180 x 180 DPI)

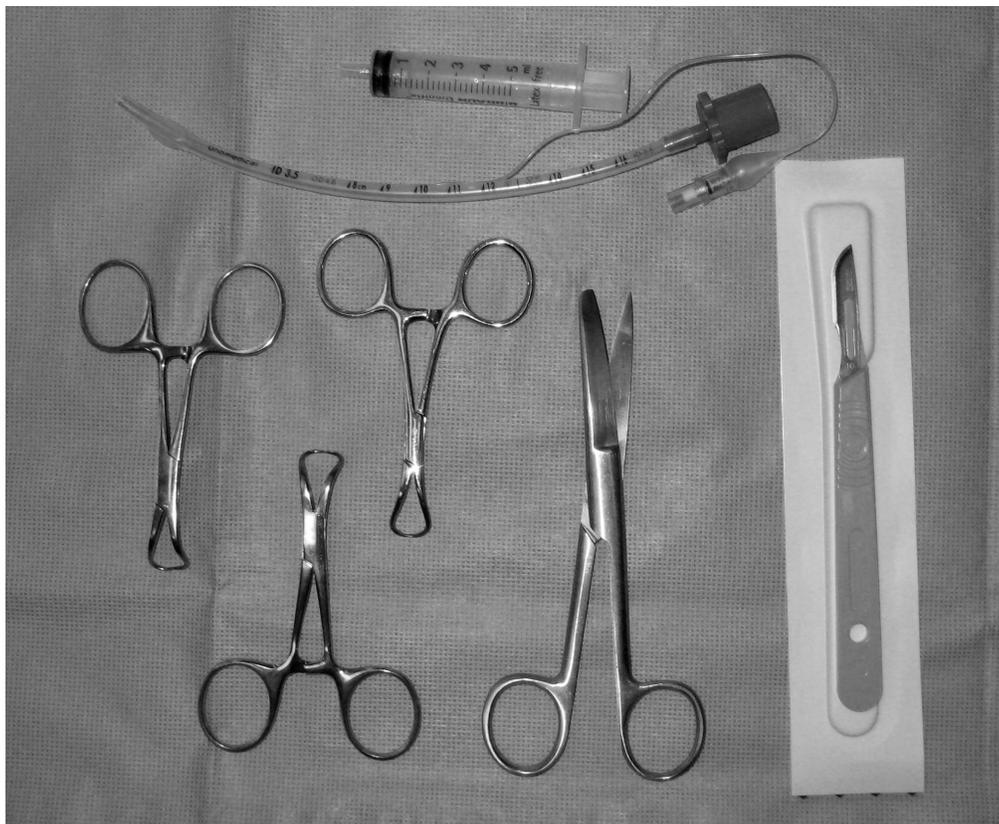
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Three-way stopcock used for jet ventilation.
320x245mm (180 x 180 DPI)

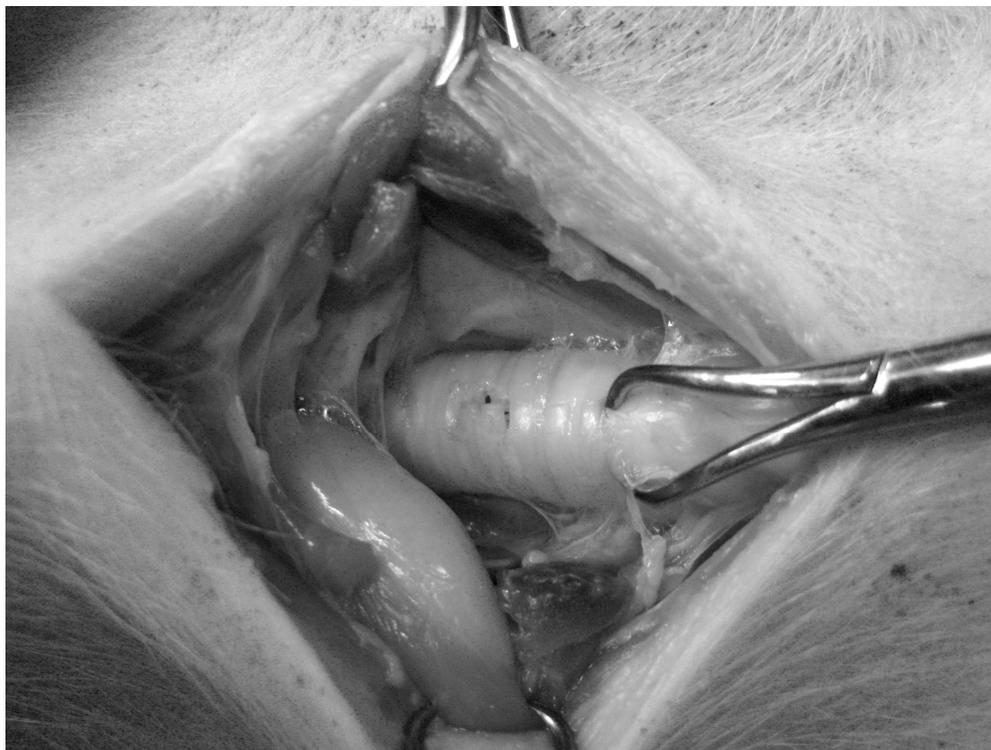
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Tools for emergency tracheotomy. Scalpel, nurses scissors, 3 towel forceps.
285x235mm (180 x 180 DPI)

view



Trachea is presented and stabilised and the strap muscles held aside with three towel forceps. A hole has been cut with in two tracheal rings with the scissors.
433x325mm (180 x 180 DPI)

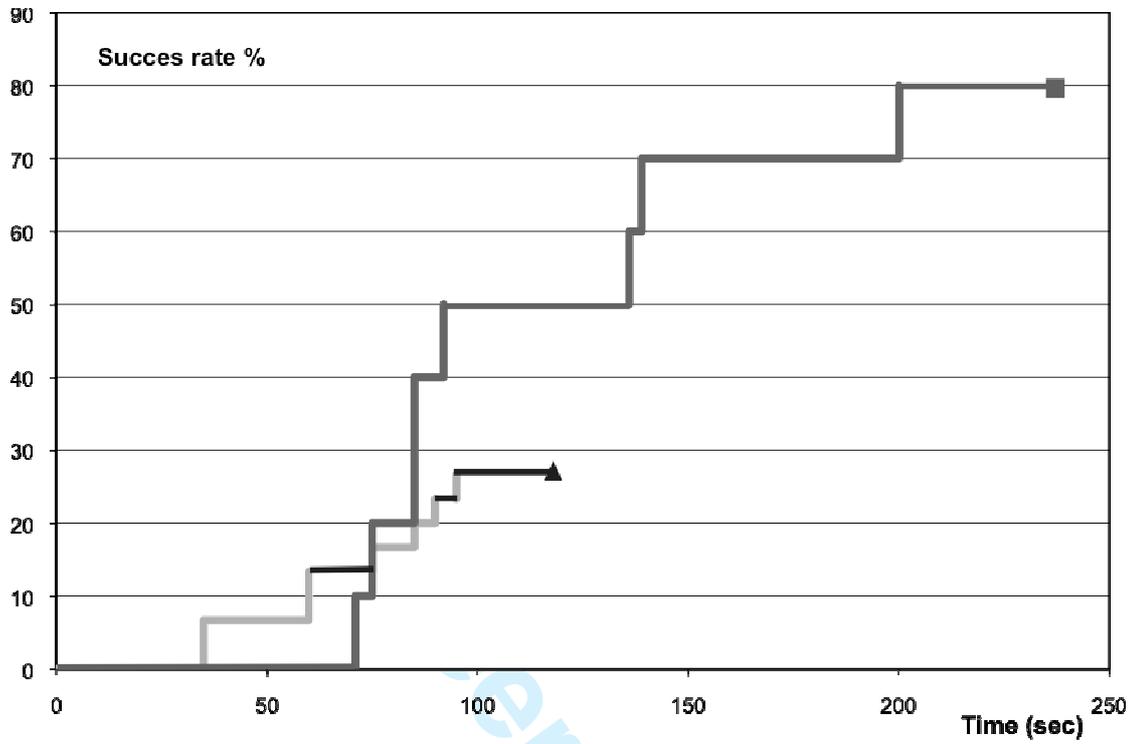
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| | Transtracheal cannula N=30 | Surgical tracheotomy N=10 | P |
|-------------------------------------|-------------------------------|------------------------------|-------|
| Success | 8 (27%, 14-45%) | 8 (80%, 48-95%) | 0.007 |
| Time for successful attempt, sec | 68 (35-95) | 89 (71-200) | 0.08 |

For Peer Review

Figure 5. Kaplan-Meier analysis of time and success for performing transtracheal cannula (▲) and tracheotomy (■).



Peer Review

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For Peer Review

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| Fig 1 Transtracheal cannula placement. |
| Fig 2 Three-way stopcock used for jet ventilation. |
| Fig 3 Tools for emergency tracheotomy. Scalpel, nurses scissors, 3 towel forceps. |
| Fig 4 Trachea is presented and stabilised and the strap muscles held aside with three towel forceps. A hole has been cut with in two tracheal rings with the scissors. |

Table 1. Time and success rate for obtaining access to the piglet airway, either by insertion of the transtracheal cannula or by performing surgical tracheotomy.

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