

RESEARCH ARTICLE

Implementation of a new technique to improve subglottic secretion mobilization in tracheotomized ICU patients: The "volcano method"

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Abstract

Background: Ventilator associated pneumonia is a challenging complication in tracheotomized patients. One key problem is effective drainage of subglottic secretion. We have implemented a new method for subglottic secretion clearance. In the (so-called) volcano method, air is insufflated through the subglottic suction line of the tracheostomy tube, to blow secretion up to the mouth, where it is suctioned out from there.

Objective: To describe the clinical implementation process of the volcano method, including patient allocation according to a defined decision-tree, and to assess ICU health care professionals' knowledge and opinion about the newly implemented method.

Methods: Mixed-methods implementation study, consisting of a three-step procedure.

1. Development of educational material and processes.
2. Pilot-testing with description of patient selection.
3. Survey on health care professionals' knowledge and opinion about the volcano method.

Results: Key aspects of the preparatory phase were the development of a standardized operating procedure, and an educational video. During the three-month pilot-testing phase, 56 patients were admitted to the ICU, and 10 (18%) were finally treated using the volcano method. Out of the 85 employees of the ICU 36 (42%) filled out and returned the questionnaire. Most of the health care professionals strongly agreed on the feasibility and effectiveness of this method and felt confident with the maneuver. Most of them had no knowledge about this method before implementation.

Conclusions: This study successfully shows how a new method in draining the subglottic secretion can be established in a multi-disciplinary ICU team, within a short period of time.

Keyword: critical care, mechanical ventilation, ventilator associated pneumonia, tracheostomy, suction, vocalization, ventilator weaning

Introduction

Ventilator associated pneumonia (VAP) belongs to the major clinical challenges among ventilated intensive care unit (ICU) patients. The incidence for VAP varies widely from 5% to 40% depending on the setting [1]. It is well-known that VAP increases mortality, prolongs ICU and hospital stays, with prolonged ventilation days and thus increases health care costs [2,3]. VAP is associated with worse prognosis, when diagnosed in ICU patients, and mortality rates range from 12%-48% [4,5].

The risk factors that determine the onset of VAP have been thoroughly classified and researched. A major determinant of VAP is mechanical ventilation longer than 20 days. The patients underlying disease, which determines the length of mechanical ventilation, has a direct impact on VAP incidence [6]. Similarly the type of tracheostomy tube (or endotracheal tube) used during mechanical ventilation is another important factor. Cannulas or tubes with subglottic secretion drainage (SSD) can reduce the early onset of VAP by up to 45% [7]. Other major risks include patient's age, immunosuppression, and protective swallowing reflex, pre-occurrence of respiratory diseases, prolonged intubation time, re-intubation, and sedation [8]. To address these risk factors, VAP-bundles were commonly implemented in ICUs [9,10]. Nevertheless, VAP prevention remains challenging, as there lacks a gold standard technique and many different interventions

are combined in a VAP bundle. One essential preventive intervention proposed in VAP bundle is SSD [11].

SSD plays an important role in the prevention of VAP, has a favorable impact on VAP-Incidence rates and is associated with a significant decrease in VAP [7,12,13]. However, implementation of SSD has limitations, as it depends on numerous factors. The most important being the amount of secretion produced by the patients, and their inability in managing the secretion produced owing to certain factors such as analgosedation, reduced functional sensibility of the laryngeal parts involved in swallowing and therefore resulting in a reduction of swallowing frequency. Similarly other factors include practice among ICUs in secretion management, efficiency, and efficacy in such practices depending upon individual nursing ICU-staff. Individualized management, based on the volume of subglottic secretions produced by patients, can further optimize the airway management, and reduce the risk of adverse events of subglottic secretion aspiration [14]. Unfortunately there is no gold standard defined of how the subglottic secretion present above the cuff can best be drained. In current ICU practice, suctioning is performed through the suction line attached to endotracheal tubes or tracheal cannulas.

Our clinical evidence suggests that with common suctioning techniques through subglottic suction line, sufficient cleaning of the trachea may not be reached. It has also been seen in clinical use, that

depending upon the quantity of subglottic secretion, as well as its viscosity, the existing secretion often can't completely be removed by suctioning through the suction line. Therefore, in this circumstance we suggest an alternative technique, in which mucus residing in the subglottic region above the cuff is blown up into the mouth and then suctioned from there. Like a volcanic eruption, the injected air would lift the secretion through the vocal cords. Therefore, we suggest the name "volcano method" for this technique. This method is not completely new and has been practiced by speech and language therapists in patients with tracheostomy tubes during above cuff vocalization (ACV) [15]. However, with a completely different goal. Interestingly, a higher amount of secretion mobilization has been noticed as a side effect by our speech and language therapists as well as the attending physicians in clinical practice.

Therefore, we hypothesize that clinical implementation of the volcano method is feasible to optimize secretion management in a specific group of tracheotomized ICU patients. The concrete aims of this study were 1) to develop a standardized operating procedure (SOP) for clinical use; 2) to describe the patient's selection process; and 3) to assess the ICU health care professionals' knowledge and opinions on this new method.

Material and methods

This mixed-methods implementation study was conducted in the ICU setting of a large neurologic rehabilitation hospital in Switzerland, with ten beds for ventilated patients. This ICU is specialized in patients with spinal cord injuries and prolonged weaning sessions. Our study collected qualitative and quantitative measures over the implementation period of this new method, which lasted from May 2024 until end of November 2024. Within this timeframe, a three-step implementation procedure was conducted:

1. Preparatory phase: development of educational material and processes (SOP)

2. Three-month pilot-testing: patient selection and conduction of the volcano method

3. Survey: a qualitative assessment on ICU health care professionals' knowledge and opinion about the volcano method

These three steps are described in detail below:

1. Preparatory phase: before practical implementation of the volcano method in ICU, the following steps were conducted.

- Project presentation and approval from internal "Breathing Advisory Board" consisting of internal physicians, nurses, speech and language therapists.
- Development of the SOP "volcano method" (Supplement File 1)
- Preparation of an SOP based training video for ICU health care professionals
- Hands-on-training for ICU health care professionals
- Advise physicians to prefer tracheal cannulas with a subglottic tube

Conduction of these five steps were done within approximately three months, between May and July of 2024.

2. Three-month pilot-testing phase: The aim of this pilot-testing phase was to get an estimate about the percentage of all ICU patients eligible for treatment, and to get a first impression about feasibility of the volcano method. The preconditions, among ventilated and tracheotomized patients were:

- swallowing disorder with a Penetration-Aspiration-Scale-Score >7 [16]
- high amount of secretion production
- an appropriate tracheal cannula with a subglottic secretion wing

All ICU admissions between the 1st of August 2024 and the 31st of October 2024 were screened for eligibility to conduct the volcano method, according to the decision tree presented in figure 1.

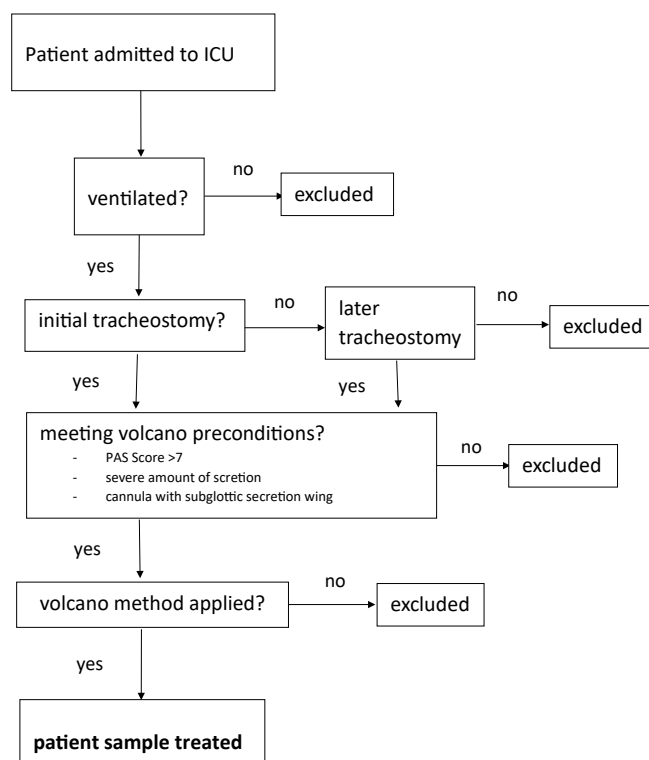


Figure 1. Decision tree on patient allocation to the volcano method.

The concrete procedure including devices and preconditions to conduct this method is described below.

Volcano-procedure and operative preconditions: Oxygen supply present in ICU rooms was used to insufflate through the suction line (a) Oxygen flow was regulated through an analogue valve regulator (b) Turning regulator wheel counterclockwise increased the flow, and turning it clockwise reduced the flow. A flow of 2-3 liters per minute was sufficient to regurgitate subglottic secretion. Air blown in was regulated and adjusted according to the patient's tolerance. Oxygen flow could be increased, when needed, up to 6 liters per minute. The analogue valve regulator supplying oxygen was connected via a plastic tube with an adapter (c) The adapter (d) had a fingertip regulator (e) for fine adjustment of the air blown into the tracheal cannula (g) suction line (f) (Figure 2). Finally, the mobilized secretion was suctioned pharyngeal and oral using a suction tube (Charrière, size CH14). Before air insufflation, the patient's oral secretion was suctioned thoroughly through mouth. This procedure was performed bedside, by the patient's attending ICU nurse, whilst a second nurse in charge was responsible for oxygen flow regulations. Total time needed for the complete procedure was about 3-5 minutes and it was performed once about every eight hours.

3. Survey: An anonymized qualitative assessment of the health care professionals' knowledge, and their opinion on the volcano method, was drafted for four ICU working groups involved: nurses, physicians, speech and language therapists, and physiotherapists. The questionnaire used consisted of following seven questions:

- Are you familiar with subglottic suctioning?
- Did you have any prior knowledge regarding this method before its introduction in ICU?
- Were SOP and the video introduction helpful in practical implementation?

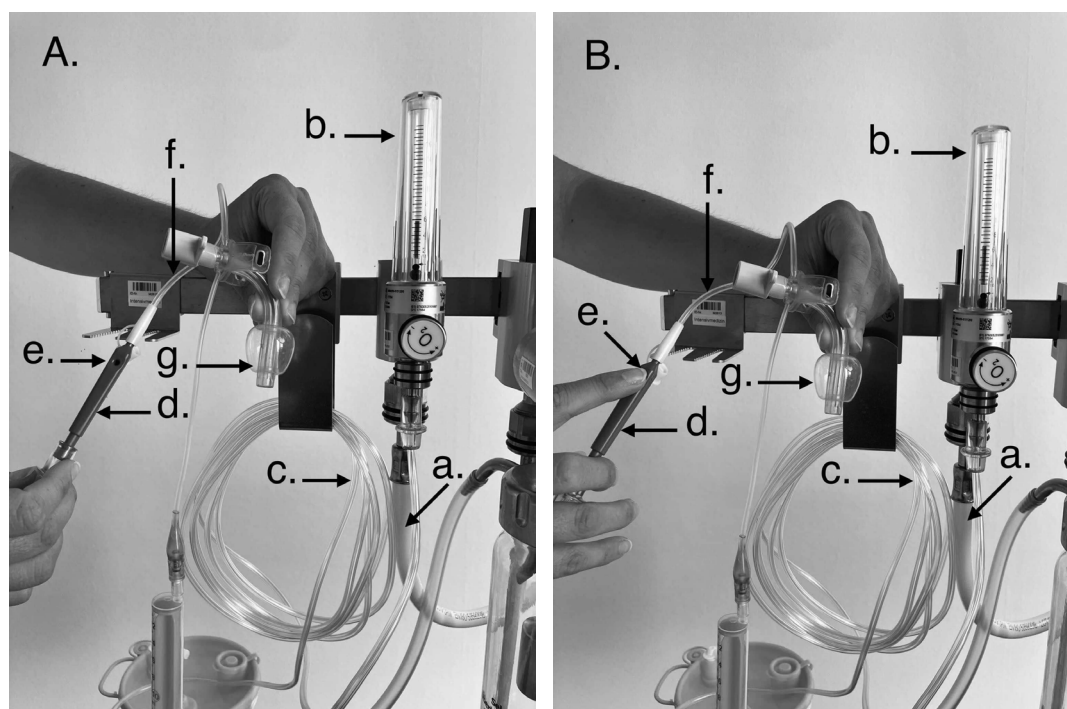


Figure 2. A: Technical setup required for application of the volcano method, and 2 B: addition with fingertip application for finer flow adjustment. Legend: a.) room oxygen supply; b.) analogue oxygen valve regulator; c.) oxygen flow tube to patient; d.) adapter (Spiggle & Theis, single use suction handles); e.) fingertip regulator; f.) suction drainage tube; g.) tracheal cannula (Traceo, with subglottic suction aid).

4. Is this method practical, and easy enough to perform?
5. After the three-month introductory period, do you feel confident in performing this procedure?
6. Do you think this method can contribute to secretion mobilization, in addition to subglottic suctioning?
7. Do you think this procedure can contribute to reducing ventilator associated pneumonia in ICU patients?

For each of the following questions answer options were given on a 6-point Likert-scale: strongly agree (1); somewhat agree (2); neither agree/nor disagree (3); somewhat disagree (4); strongly disagree (5); don't know (6)

These questionnaires were printed on paper and placed in ICU common room, where all ICU employees had access. A collection shelf for anonymously filled questionnaires was also placed nearby. All ICU employees were informed personally and through E-mail to answer this questionnaire. After a week of dispatch, a reminder was initiated via internal newsletter.

The questionnaire collection period was from November 1st until November 15th, 2024.

Statement of ethics and informed consent

Based on Swiss law, and Swiss Human Research act, this qualitative study does not fall within the scope of the Swiss Human Research act and therefore needed no written informed consent of the patients. All data were assessed completely anonymous. The ethics committee north-west and central Switzerland (EKNZ) confirmed this under the approval number: Req-2024-00607, date: May 2nd 2024. The research described in this study was conducted in accordance with the World Medical Association Declaration of Helsinki [17].

Results

The first step to implementation of this new method, in improvement of secretion clearance, has primarily been initiated by ICU physicians with strong support from speech and language

therapists. People familiar with this method, which included physicians, as well as speech and language therapists, prepared SOP, produced an educational video, and executed hands-on training for nurses.

During the three-months of pilot-testing phase, 56 patients were admitted in ICU. Patient selection process for application of the volcano method is shown with the help of flowchart in figure 3 and has been conducted according to the decision tree shown in figure 1 (methods). Overall, 10 patients, or 18% of all admitted patients in the ICU and 50% of all ventilated patients were finally treated with the volcano method. Selection of an adequate type of cannula with a subglottic suction line was a key component in the successful conduction of this procedure. Eleven patients underwent cannula exchange before this method could be applied. These patients were admitted in the ICU with various diagnoses. But common key problems were: prolonged weaning, massive swallowing disorders, primary and secondary neurological disorders related to weak orotracheal and diaphragmatic function.

Survey of opinions and knowledge about the volcano method, performed among the health-care professionals working in the ICU, and showed a good response rate of 44%. Exact numbers of employees and their response rates, overall and for each health care profession separately, are shown in table 1.

Their responses were generally very positive. Responses to the seven listed questions above are presented in figure 4.

Discussion

This study describes a successful three step implementation procedure regarding the volcano method in the improvement of SSD in a multi-disciplinary ICU team. This mixed-methods study provides a concrete description of the volcano method, and an example of how such a method can be implemented within six months, in a complex multi-disciplinary ICU setting. Once implemented, and the ICU health care professionals are trained, this method can be applied in five additional minutes per patient / treatment session. In our setting, 18% of all ICU admissions, and 50% of all ventilated

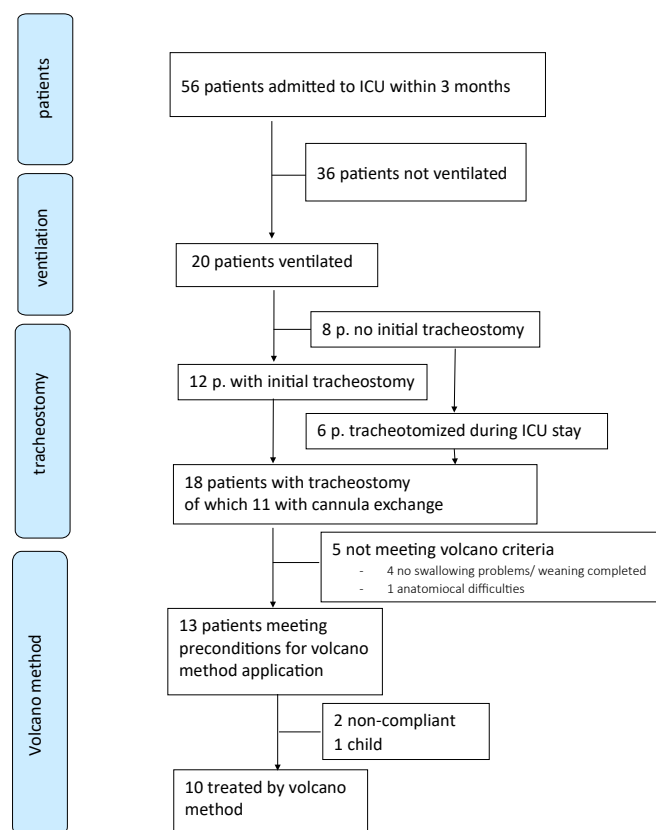


Figure 3. Flow-chart of ICU patient selection for application of the volcano method.

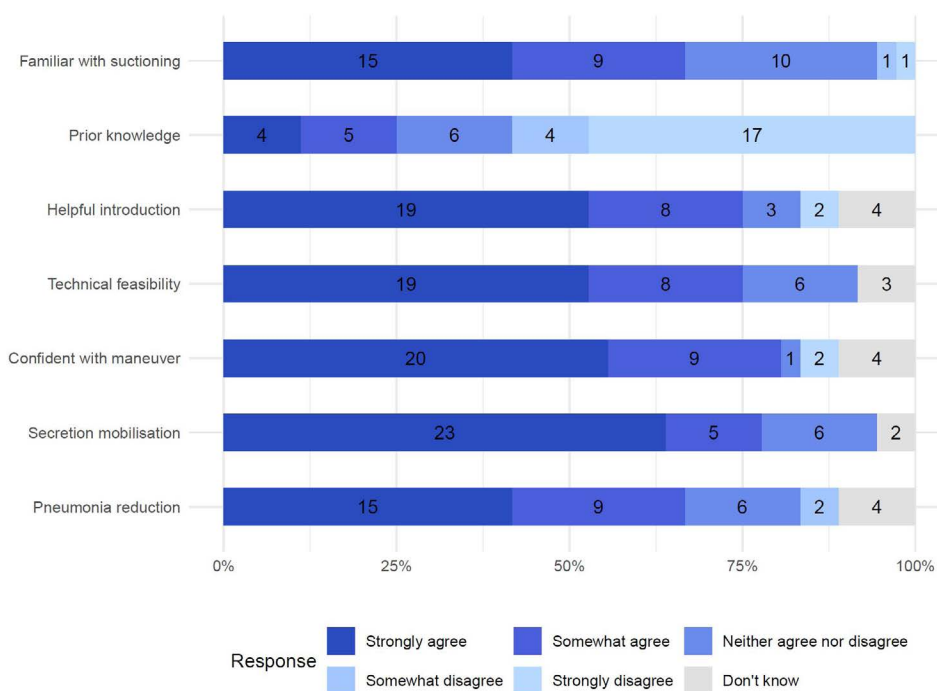


Figure 4. Overview on the responses to the survey on the volcano method.

Table 1: Number of ICU employees overall and per professional group with response rates on the questionnaire.

Group	Employees (N)	Responses (N/%)
Overall	85	36 / 42%
Nurses	65	30 / 46%
Physicians	13	3 / 23%
Physiotherapists	4	3 / 75%
Speech and language therapists	3	0 / 0%

patients were qualified for the volcano method. Afterwards, Health care professionals' attitudes were very good, even though most of them had no prior knowledge of the volcano method.

A key component for successful implementation may have been a general agreement on the importance of this new treatment method, as well as the willingness of all team leaders, along with head physicians, to make an additional effort. This involved developing SOP, preparing educational videos, providing clinical hand-on-support, and team motivation. Similarly, immense experience in cannula management among ICU health care professionals also played an important role in smooth implementation of such a new method. Additionally, detailed and regular interdisciplinary teamwork provided a good functional background. Initial idea of SSD using the volcano method came from long-term observation of secretion mobilization by speech and language therapists, as a byproduct of ACV. ACV has been used internationally for years and has been established as a safe method for initiating, activating, and maintaining involvement of laryngeal organs in speech production throughout ventilation period [15,18,19]. Thus, there is no need to additionally prove the clinical safety of this method again.

Although well known that SSD plays a very important role in VAP prevention in ICUs, it is not obvious that management of SSD is an easy and routine procedure [13,14]. This highly depends on respective ICU-settings and their experiences. ACV is not a new method for our speech and language pathologists, which builds up the base for the volcano method [15,18,19]. Initially it was not an easy task to establish the pre-implementation procedure, as well as to practically implement this clinical procedure. Also, the preliminary bias of eminence-based handling, among health-care professionals, was a very important contributing factor. An important discussion among ICU staffs was the idea that tracheal cannulas with suction line would prolong weaning, as different cuffs used in such cannulas (size and structure) would increase irritation in patient's tracheal parts, and thus have adverse effects. However, comprehensive and regular support from speech therapists, as well as strict instructions to follow the SOP, were main facilitators that improved implementation of the volcano method. Once the ICU health care professionals were convinced of these basic aspects, as well as their importance, implementation proceeded smoothly.

Once the patient's initial problem of prolonged respiratory deficiency is overcome, with the help of tracheostomy, these patients are ventilated using an adequate cannula. After that, cannula management is a top priority and needs a lot of experience. Based on this experience and different clinical features: patient's swallowing criteria (intensively evaluated by speech and language therapists), neurological disorders, overall muscular function, and a day-to-day re-evaluation of these aspects, an appropriate cannula to overcome patient's momentary functional deficits is chosen. Depending upon the stated features above, an appropriate cannula for the respective patient does not always need to be one with a suction line. Despite these strict and various preconditions, 77% of all the volcano eligible patients finally underwent this new procedure.

Our analysis regarding the patient selection procedure showed that approximately 50% of tracheotomized patients qualified for the treatment with the volcano method. After initial training period, and an additional three-month pilot testing period, ICU health care professionals responsible for this new method (nurses and physicians) had a positive opinion about the volcano method, which seems to be an important facilitator in such an implementation process.

Our 42% response rate in survey of ICU health care professionals involved (Table 1) was quite good, and within the range of other comparable surveys in ICU settings [20,21]. Overall 46% of ICU-Nurses, 23% of ICU-Physicians, and 75% of ICU-Physiotherapists responded to our survey. Surprisingly, speech and language therapists'

responses lacked. Unfortunately, this was because of an underlying communication gap with the speech and language therapists. Analyzing these responses, the ICU health care professionals had good theoretical prior knowledge about subglottic secretion management, but the volcano method seemed to be completely new to these groups too. They found SOP implementation, as well as video trainings very helpful, and seemed to be convinced that practical implementation process was quite easy. From our point of view, the questionnaire above used exactly reflects the practical learning curve of the volcano method. The efficiency of implementation was positively welcomed by the ICU nurses. Furthermore, the ICU-staff/nurses involved were convinced that the volcano method could positively help in secretion mobilization, since they could often observe a bigger amount of oral secretion suctioned after its application. This paves a way for a new study which could quantify the amount of sputum that could be drained using the volcano method.

In conclusion, the more the volcano method helps in the successful subglottic drainage, the more it could help in preventing VAP incidence. This again paves the way for a study that could compare VAP incidence before and after implementation of the volcano method.

Strengths and limitations

The patient selection process, as seen in the flow chart (Figure 3), is very specific for ICU conditions at the hospital where this study was performed, where respiratory weaning process is indeed a core problem among a high percentage of their ICU patients. Although, it may not represent the ICU conditions of other institutions, there is no limitation that prevents volcano from being applied among other tracheostomy patients. These results clearly state that this method can be applied to a substantial percentage of tracheostomized patients in an ICU.

Overall questionnaire response of 42% was quite good. This mainly reflects the ICU nurses with 46%, whilst ICU physicians with 23% seem less representative. Physiotherapists with 75% ought to be evaluated very critically, because of their small number, and basically not being directly involved in the practical implementation. Surprisingly there were no responses received from speech and language therapists. This would have been very interesting since they played an important role in developing SOP, as well as training the ICU staffs. This was due to the lack of communication flow among speech therapists in the ICU department. Different channels of communication that were used unfortunately didn't reach our speech and language therapists. It would also have been very important to know the patient's feelings and tolerance towards this new method. However, most patients treated with this method could not communicate properly because of their laryngeal organ dysfunctions.

Conclusion

The volcano method can be clinically well implemented among ICU patients if ICU staff/nurses are trained and helped respectively. Around 50% of ventilated patients may qualify for the application of this method, and potentially profit from improvement of the subglottic secretion clearance. ICU physicians, and nurses, are key health care professionals for the implementation of this method, and proper training of these professional groups seems to be important for a smooth and successful implementation procedure. Further research is needed to evaluate the concrete effects on secretion clearance and associated pulmonary infections (such as pneumonia).

Disclosure

Author contributions

BN is the principal investigator of this project. BN, LB, and GM designed the study, and all authors listed made substantial

contributions to the conception and or design of the work. GM provided methodological support in the study design. LB and RL provided clinical support. BN drafted the work. All authors of this manuscript revised it critically, for important intellectual content, and gave final approval of the version to be published. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy, or integrity, of any part of the work are appropriately investigated and resolved.

Conflict of interest

Mueller Gabi has been invited for a keynote lecture by ISCOS (International Spinal Cord Society) at the Annual Scientific Meeting 2024 in Antwerp, Belgium; Travel-, Hotel and Conference costs were covered by ISCOS. Niraula Birat Bikram; Brendebach Luca; Lenherr Renato; Perret Claudio; Probst Ilona; Mostberger Sven and Stierli Sarah have no conflict of interest.

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