Cough, expiration and aspiration reflexes: possible anesthetic implications – a brief review

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Abstract

Systematic study in animals indicated, that in addition to cough there are 2 distinct airway reflexes. The aspiration reflex (AspR) characterized by rapid and strong gasp-like inspiration provoked by stimulation of nasopharynx, nasal phyltrum or auricle of ear. The expiration reflex (ExpR) manifests by prompt expiration, induced by laryngeal stimulation. Both reflexes strongly activate the brainstem inspiratory or expiratory generators, respectively, and inhibit the opposite respiratory and various functional disorders.

This paper indicates several functional disorders occurring during manipulation with airways in anaesthesiological practice, which can be influenced positively or negatively by application of these special reflexes (asphyxia, breath-holding, bronchospasm, sleep apnoea episodes, arrhythmia, collapse, etc.). The AspR, ExpR and CR (cough reflex) have important clinical relevance in anaesthesia and emergency medicine applicable also in domestic therapy and in hardly accessible places particularly by application of ICT (Information & Communication Technologies) using a mobile connection of the patient with the remote hospital centre.

Keywords: aspiration reflex, breath-holding, bronchospasm, expiration reflex, cough

Introduction

Airway stimulation evokes well described reactive responses, such as cough [1-6], laryngospasm [7-11] and bronchospasm [12-15]. These reflex responses may also occur during light anesthesia. Additionally to these, two other reflexes, the expiration and aspiration reflexes have been described, though their precise mechanisms of action and implications in clinical practice have not been clearly identified. Nonetheless, both expiration reflex (ExpR) and aspiration reflex (AspR) might have important implications in various pathological processes in the anesthetized patients and in other conditions unrelated to anesthesia.

The purpose of this brief review is to familiarize the anesthesiologists with the possible implications of ExpR, AspR and cough reflex (CR) in various situations encountered in anesthesia practice.

Disclosure: Part of the text content relies on clinical observation and assumptions rather than being based on evidence or other published literature.

Description and basic pathophysiology

Table 1 lists the ten main components of AspR, ExpR and CR and Figure 1 schematically illustrates and compares them with quiet breath.

The ExpR has been described as a solitary, short-lasting activity of the abdominal muscles, indicating a prompt expiratory effort with no preceding inspiration, with reflex interruption of an occasional inspiration. It
Table 1. Main parameters of aspiration, expiration and cough reflexes

<table>
<thead>
<tr>
<th>Reflex</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Aspiration</td>
<td>Accompanied by transient bronchoconstriction.</td>
</tr>
<tr>
<td>Cough</td>
<td>Distinguished by a laryngeal closure and forceful expiration.</td>
</tr>
<tr>
<td>Expiration</td>
<td>Provides tracheal protection against aspiration.</td>
</tr>
</tbody>
</table>

Clinical relevance of airway reflexes

- **Possible implications of ExpR, CR and AspR in anesthetic scenarios**
- In an awake or lightly anesthetized patient, breath holding, "on the endotracheal tube" occasionally called by some authors as "cough and strain afterward" [9] is a well-known anesthetic problem. This strain after...

- **Expiratory Reflex**
  - Occurs with a reflex increase in transmural pressure...
  - Indicating a reduction in abdominal and other expiratory musculature...
  - Long-lasting laryngeal closure and forceful expiration...
Airway reflexes

Breath holding with desaturation is also not uncommon after extubation of the trachea. A typical clinical picture is convulsive expiratory movements (“strain”) of chest and abdomen and difficulty to ventilate the patient through a facemask. Often, this is related to laryngospasm though the manifestations of ExpR and laryngospasm seem to be different. This is especially evident with partial laryngeal closure often manifested by stridor which is absent in the case of ExpR. We thus speculate that in post extubation breath holding, similarly to a “strain” on the endotracheal tube, the patient holds his breath during expiration and cannot generate inspiration effort supposedly owing to an active ExpR, whereas during laryngospasm the patient cannot drive gas into the lungs because of upper airway obstruction.

ExpR may also be activated as an exaggerated response to aggressive upper airway manipulations. In our clinical experience, this can be encountered in lightly anesthetized pediatric patients and morbidly obese patients, especially in those suffering from obstructive sleep apnea.

The AspR, another defensive airway reflex, might explain the mechanism of post-obstructive negative pressure pulmonary edema following a laryngospasm, because it manifests by strong, gasping movements that can create excessive negative pressures in the chest cavity.

**Manifestation of ExpR, CR and AspR in emergency medicine scenarios**

The ExpR may play an important role in children suffering from “Breath-holding spells”, where breath-holding and desaturation occur at the end of expiration, instead of normally starting an inspiratory effort. Remarkably many of these children suffer from ENT (ear throat and nose) problems and improve significantly after adenoidectomy [12, 24].

Additionally, about 15% of the drowning victims have no water in the lungs (the dry-drowning phenomenon) [25-30]. The mechanism behind these phenomena may be a breath-holding, also involving ExpR.

The management of post-extubation breath holding seems to be similar to that of post-extubation laryngospasm. We empirically but successfully use rapid, shallow mask ventilation along with CPAP. Recently, Al-Metwalli [31], successfully managed post-extubation laryngospasm (or ExpR?) with gentle chest compressions. All these management tools promote air

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Fig. 1. The 10 main components of AspR, ExpR, CR compared with quiet breath. Abbreviations: 1) EMG_d – diaphragmatic electromyogram, 2) EMG_ab – abdominal electromyogram, 3) P_pl – pleural pressure, 4) V’ – airflow, 5) P_tm – transmural pressure, 6) Tr – tracheal lumen, 7) Gl – glottal lumen, 8) Phono – acoustic signal of breathing, 9) ENG_b – electroneurogram of a bronchoconstrictor fiber activity, 10) V_T – tidal volume. The axis for airflow and P_tm is on the right side of the figure, but the P_pl label is on the left (with permission from: Z. Tomori, I. Poliacek, J. Jakus, J. et al. Distinct generators for aspiration and expiration reflexes: localization, mechanisms and effects. J Physiol Pharmacol 2010; 61(1): 5-12)

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movement within the chest and thus, supposedly help brake the ExpR and/or laryngospasm.

**Revitalization and resuscitation effects of airway reflexes**

Gasping respiration observed in infants in critical conditions before death has a strong resuscitation potential. Survival or death depends on the prevalence of either the gasps or the inhibitory effect on vital organs with morphological destruction or functional impairment of control mechanisms, such as in SIDS (Sudden Infant Death Syndrome [32]). Contact stimulation of the nasopharynx in cats provokes strong impulses (~200 Hz) in the glossopharyngeal afferents [33], which activate the brainstem inspiratory generator located in the pre-Botzinger complex [34]. This provokes a rapid and strong inspiratory effort, the gasp-like aspiration reflex [19-23]. The AspR has similar resuscitation and revitalization potential as gasping, proved mostly in animals [21]. Stimulation and suction by a nasopharyngeal catheter, proved to interrupt supraventricular tachycardia in 4 from 12 infants [35], similarly as in adults observed accidentally during introduction of a naso-gastric catheter for gastric juice collection [36]. Nasopharyngeal stimulation could also interrupt hiccough attacks [37]. Provocation of AspR proved to interrupt hypoxic apnoea in cats [23]. Therefore, it can speed up normalization of breathing also in artificially ventilated patients, resulting from reflex activation of the brainstem inspiratory generator [34].

Rapid sniff through the nose for one second with closed mouth, representing a voluntary equivalent of AspR has a broncho-protective and broncho-dilatory effect in patients with asthma, chronic obstructive pulmonary disease, smokers and healthy people [38, 39]. Strong activation of brainstem inspiratory generator during rapid sniff may be transferred to other central structures and may dilate the airway lumen [39], or inhibit various pathological states such as laryngospasm, bronchospasm, Parkinson’s tremor, epileptic seizure, etc.

Sudden hypotension with imminent loss of consciousness caused by anaphylactic reaction or other reasons such as ventricular arrhythmias can be prevented by cough “on demand” [40]. The deep inspiration of cough ("sniff and expire") increases venous return and the successive strong expiratory effort provides prompt brain perfusion to prevent a collapse.

The persisting AspR might allow differentiation of patients in a vegetative state by the presence of activity in the pre-motor area of brain in fMRI on the instruction to move the hand, from non-reacting patient with brain death [41]. Similar activities might also be observed by fMRI after provocation of AspR by mechanical means even in more severe disorders of consciousness without voluntary but persisting reflex signs. Since AspR persists even in the stage of pre-mortal gasping at least in cats, the procedure might allow exclusion of brain death in selected cases of moribund patients [22].

The persisting AspR and ExpR, representing diametrical different reactions, as binary signals allow for paraplegics to communicate using a computer and control their wheelchair, as described by Plotkin et al. [42].

**Conclusion:** In this review we tried to familiarize the anesthesia and intensive care medicine specialties readers with the concepts of ExpR, CR and AspR and their possible clinical relevance, including in the field of anesthesia and emergency medicine.

**Conflict of interest**

Nothing to declare

**References**

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Airway reflexes

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Tusea, reflexul expirator şi de aspiraţie: implicaţii anestezice

Rezumat

Studiul sistematice pe animale au arătat că există două reflexe suplimentare ale căii aeriene pe lângă reflexul de tuse. Reflexul de aspiraţie (AspR) este caracterizat printr-o inspiraţie rapidă şi puternică (“gasp-like”) provocată de stimularea nazofaringelui, filtrului nazal sau a pavilionului urechii. Reflexul expirator (ExpR) se manifestă printr-o expiraţie promptă indusă de stimularea laringiană. Ambete reflexe activează puternic centrii respiratori care generează inspiraţia, respectiv expiraţia, inhibând reflexul de aspiraţie voluntară. Această lucrare semnează cătiva tulburări funcţionale care apar din cauza manipulării instrumentale a căii aeriene în timpul practicii anestezice şi care pot fi influenţate pozitiv sau negativ prin aplicarea acestor reflexe particulare (asfixia, apneea voluntară, laringospasmul, bronhospasmul, episodele de apnee de somn, aritmii, colaps etc.). AspR, ExpR şi reflexul de tuse au o importanţă particulară în practica anestezică şi în medicina de urgenţă, cu aplicabilitate şi în terapia la domiciliu, chiar şi în locuri aflate la distanţă mai mare de spital, prin utilizarea unei legături telefonice mobile cu pacientul.

Cuvinte cheie: reflex de aspiraţie, apnee, bronhospasm, reflex expirator, tuse