Bronchoesophageal and Related Systems in Space Flight

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The human bronchoesophageal system evolved with the capacity to function under many conditions and has functioned during space flight without difficulty. In contrast, other systems, e.g., the vestibular system, have uniquely adapted to the gravity of Earth and in weightlessness must have time to adapt to a new environment. Still others, after adaptation, are unable to function normally on return to Earth, e.g., the cardiovascular and musculo-skeletal systems. Since there have been no problems, the bronchoesophageal system has been inadequately studied in flight and little can be said about it other than it appears to function normally. Conversely there have been a number of problems in associated areas, especially gastric. The following is a brief review of these related areas in space flight.

Prior to human space flight many problems, some potentially fatal, were predicted including difficulty in swallowing and aspiration of food and liquid. In early flights, food particulates were especially feared by ground researchers and early foods were pastes contained in tubes.

Swallowing consists of propulsion of small masses of liquids and semi-liquids by relatively large muscle forces which are controlled by simple local reflexes. A single study of intraesophageal pressures, using a miniature transducer on a naso-gastric catheter, including the sphincter and with swallowing, showed unchanged pressures and patterns in flight. Respiratory gas transport is protected by a remarkably efficient valve arrangement, exquisitely coordinated with swallowing. Observation of children at play with food and drink illustrates this, for they are frequently eating and drinking in a variety of positions including head down. There have been no difficulties with either swallowing or aspiration in flight and a wide variety of normal foods are now allowed. Table 1 lists symptoms in associated areas.

After a few hours in flight, in addition to reduced nasal patency, the facies are puffy, especially in the periorbital areas, and legs are noticeably thinner. Russian cosmonauts speak of a 'rush of blood to the head.' After approximately a week in flight, the subjective symptoms are reduced but from pictures taken on Skylab after weeks in flight, facial fullness remains. At all times in flight the external jugular and many superficial cephalic veins are distended.

Another common experience is decreased or altered sense of taste, and flavorful and highly seasoned foods and increased spices become popular with some crewmen. It appears that all of these phenomena may be caused by absence of hydrostatic pressure in the vascular system. The dominant posture on Earth is upright. In this posture, all blood pressure above the heart is reduced while pressures below the heart are...
TABLE I. In Flight Symptoms

- Stuffy noses
- Olfactory and taste changes
- Nasopharyngeal irritation
- Voice changes (with atmospheric change)
- ‘Wet burps’ (belching)
- Epigastric sensations
- Anorexia and sudden vomiting
- Occasional nausea

increased such that venous pressure is reduced to zero at the base of the neck and arterial pressure is typically reduced by 25 to 30 mmHg at eye level. The continued changes in pressure in flight removes one to three or more liters of tissue fluid from the legs and produces edema of nasal mucosa and facies with increased air flow resistance. It does not appear to cause congestion of pharyngeal tissue for there have been no symptoms of eustachian tube occlusion.

It is assumed that this congestion may affect olfactory sensors or their ventilation and account for the changes in taste/olfaction noted. Cough reflexes appear unchanged. Ciliary transport has not been studied but in the absence of related problem is assumed to be normal. This area is incompletely studied and many questions remain, e.g., why are the tissue fluid changes seen in weightlessness so much greater than those experienced in bed rest?

Naso-pharyngeal irritation may arise from a variety of gases, vapors or particulate sources, for the small atmospheric volume is poorly filtered, and trace contaminants may increase in concentration rapidly. In spite of strict specification and testing, contaminants sometimes slip through e.g., on my initial flight the LiOH used to remove atmospheric CO₂ had dust which caused eye, nose, and bronchial irritation. In early U.S. spacecraft the reduced pressure and relatively low humidity exacerbated such irritation (Table II).

When going from normal to reduced pressure such as occurred prior to Shuttle or during extra-vehicular activity, there is a noticeable upward shift of pitch in speech, which may affect intelligibility. This shift is a well known function of atmospheric density. Neither of these previous problems are unique to space flight.

A universal experience in weightlessness is to have the gas from an apparently normal belch accompanied by gastric contents. Again the problem is lack of hydrostatic pressure such that gas and liquid phases do not separate and large bubbles of gas are embedded in the liquid. While belching is triggered normally the resulting activity may propel gas and liquid or if a gas bubble is adjacent to the esophageal orifice, only gas.

One of the most studied problems in space flight is Space Motion Sickness (SMS) which secondarily involves the upper gastrointestinal tract.

SMS is a variant of Earth Motion Sickness (EMS): it affects approximately 50% of first time flyers, symptoms are less severe than EMS and always limited, resolving completely in 8-72 hours. All motion sicknesses are assumed to be caused by conflicting information from major sensory modalities and that appears to be the case here.

A number of etiologies for SMS have been proposed including changes in intralabyrinthine fluid pressure and electrolyte concentration, unbalanced otoliths, vestibular oculomotor disturbances, and somato-sensory changes. While incompletely studied, there is little evidence to date to supports these hypotheses e.g., audio evoked potentials are unchanged and oculomotor functions is little changed. The most obvious cause is a conflict between otolith organ signals, distorted by weightlessness, and normal semicircular canal signals.

TABLE II. Typical Shuttle Atmospheric Characteristics

<table>
<thead>
<tr>
<th>Pressure, total</th>
<th>101.3±1.3 KPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pp O₂</td>
<td>20.3-23.8 KPa</td>
</tr>
<tr>
<td>Temp.</td>
<td>291-299±1°C</td>
</tr>
<tr>
<td>Pp N₂</td>
<td>Total Press. - PpO₂</td>
</tr>
<tr>
<td>Humidity</td>
<td>20-60%</td>
</tr>
<tr>
<td>Pp CO₂</td>
<td>&lt;1. KPa</td>
</tr>
</tbody>
</table>

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TABLE III. Comparison of Earth and Space Motion Sickness

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Earth</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallor*</td>
<td>usual</td>
<td>Seldom seen, flushing is common unusual</td>
</tr>
<tr>
<td>Sweating*</td>
<td>usual</td>
<td>occasional</td>
</tr>
<tr>
<td>Salivation, swallowing*</td>
<td>usual</td>
<td>occasional sensation of pain or pressure</td>
</tr>
<tr>
<td>Gastric awareness*</td>
<td>usual</td>
<td>unusual, idiosyncratic</td>
</tr>
<tr>
<td>Nausea*</td>
<td>prominent</td>
<td>brief, episodic</td>
</tr>
<tr>
<td>Vomiting*</td>
<td>persistent, may be severe</td>
<td>prominent</td>
</tr>
<tr>
<td>Malaise</td>
<td>prominent</td>
<td>very prominent especially pitching motion</td>
</tr>
<tr>
<td>Motion sensitivity</td>
<td>variable</td>
<td></td>
</tr>
<tr>
<td>Anorexia</td>
<td>very prominent</td>
<td>very prominent</td>
</tr>
<tr>
<td>Lethargy &amp; Somnolence</td>
<td>prominent</td>
<td></td>
</tr>
<tr>
<td>Onset</td>
<td>minutes to hours</td>
<td>typically 1-4 hours</td>
</tr>
<tr>
<td>Resolution</td>
<td>variable, often prolonged</td>
<td>always in 8-72 hours</td>
</tr>
<tr>
<td>Severity</td>
<td>may be incapacitating</td>
<td>unpleasant but performance of trained tasks is routinely done</td>
</tr>
</tbody>
</table>

Note: These symptoms (*) usually progress in order while sudden brief vomiting may be the first sign or symptom of SMS.

One of the most striking aspects of SMS is the sudden onset of vomiting without nausea or other premonition. Bouts of vomiting are brief, appear to empty the stomach and recur only when contents are replaced by gastric secretion or food or drink. The most consistent sign of SMS is absence of bowel sounds which is consistent with a functional upper GI ileus.¹⁶

It is hypothesized that in EMS, vestibular nuclei and other sensory signals are input directly to the emesis center and may cause continued vomiting and retching to prostration. In SMS it appears that the process may produce two steps— inhibition of gastric motility with stasis and distension which then trigger the emesis center via vagal afferents. The usual absence of nausea in SMS and general ineffectiveness of medications proven effective in EMS might also argue for a different pathway for SMS. While this is speculative, it is a fact that SMS is much milder than EMS and trained, motivated subjects are able to work through this period.

Drugs, in spite of extensive usage, have been ineffective although there are several cases of onset of SMS being delayed by Scopolamine but typical symptoms developed after stopping the drug in these cases. Injected Phenergan has recently been used with claims of success. The entire area of EMS and SMS as well as questions of gastrointestinal tract control demand much additional research.

Future flights will be much longer. This will provide opportunity for the kind of mishaps to bronchus and esophagus that occur on Earth and also the opportunity for medical research not possible to date. Maximum efficiency in clinical apparatus and techniques will be required. In addition the absence of weight may affect clinical situations, e.g., both location of an ingested foreign object and techniques of removal may be altered.

Systematic investigation of function of these systems under weightlessness may add to our understanding of normal function on Earth. Plans and preparations for personnel and facilities for more extensive investigations on long duration flights with extended durations of the Shuttle and Space Station are underway. International participation, especially by Japan and Japanese medical...
personnel, is an essential part of such missions.

REFERENCES

5) Gazenko, O.G.: Space Biology and Medicine, p.50, Moscow, Hauka 1987, USSR.