SINUS BAROTRAUMA IN DIVERS

by

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SINUS BAROTRAUMA IN DIVERS

Sinus barotrauma is a dysbaric disorder affecting aviators, caisson workers and divers. It is the clinical sequel of Boyle's Law as it affects the sinus air spaces, and is second in incidence only to middle ear barotrauma as an occupational disease of divers. Most of our knowledge of sinus barotrauma is derived from aviation medicine, with little more than anecdotal information about its clinical manifestations in divers. No detailed study of sinus barotrauma in divers has previously been published. Sinus barotrauma may occur during descent, ascent or both.

PHYSICS

Boyle's Law states that, at any given temperature, the volume of a given mass of gas will vary inversely with the absolute pressure. The pressure at sea level is 1 atmosphere absolute (ATA). This is increased by 1 ATA for each descent of 10 metres of seawater. Thus at 30 metres the absolute pressure is 4 ATA and a gas space enclosed in an elastic container occupies only one quarter of its volume at sea level. Alternately an enclosed gas space will expand to 4 times its volume if it is brought from 4 ATA to sea level, 1 ATA.

PATHOPHYSIOLOGY

The mechanism of the development of sinus barotrauma is very thoroughly discussed by Campbell. Although he only discussed aircraft barotrauma the arguments he uses apply equally well to divers and bear repetition.

The paranasal sinuses consist of bony cavities lined by a vascular mucosa. The sinus cavities communicate with the nasal cavities either by simple ostia, as in the maxillary sinuses, or by a long and tortuous duct as in the frontal sinuses. The mucosa which lines the ostia connects the nasal mucosa with that in the sinuses and is affected by the same conditions as those which affect the nasal mucosa e.g. viral upper respiratory tract infections, smoking.

While the sinus ostia remains patent, pressure changes occurring in the environment and in the nasal cavities are directly transmitted to the air in the sinuses and the free passage of air in and out of the sinuses allows rapid pressure adjustment (FIG 1).

When a subject undergoing pressure increase has pus or other infected material in the nasal cavity, this pus will be forced through a patent sinus ostium into the sinus itself (FIG 2). If a secondary inflammatory condition is then established in the sinus itself it constitutes a non-obstructive sinusitis.

More frequently a mechanical obstruction prevents the free flow of air in and out of the sinus. Polyps, a deflected nasal septum or a new growth (FIG 3) produce such a mechanical obstruction. In addition a viral upper respiratory tract infection and smoking cause mucosal swelling in the narrow sinus ostium itself with a similar result.

While the bony walls of the sinuses are themselves relatively rigid, the entire sinus wall is not a rigid system (FIG 4). The bony wall is pierced by multiple apertures for the transmission of nerves and blood vessels. These apertures enable pressure changes occurring on one side of the wall to be transmitted to the other.
FIG. 1

1 ATA

Pressure transmitted freely throughout the entire system of the sinus ostia.

Nasal cavity
Sinus cavity

3 ATA

FIG. 2

Pus in middle meatus

Increasing Pressure

Pus forced through the patent sinus ostium by pressure increase.
FIG. 3

Redundant mucosa forming a flap-valve

Closure of flap valve by external pressure increases

Stage of mucosal swelling

Stage of free hemorrhage

FIG. 4

Bony wall

Sinus mucosa

Skin

Muscle and periosteum
Consider a diver with a blocked sinus ostium during descent. The external pressure increase is transmitted through the sinus wall leading to vascular congestion and oedema in the sinus mucosa. At the same time the air in the sinus cavity, in accordance with Boyle’s Law, decreases in volume.

When the elastic limit of the mucosa is exceeded, haemorrhage will occur, either into the mucosa itself, the submucosal space or the lumen of the sinus.

It is probable that these changes in the mucosa are responsible for the production of pain.

When ascent commences, the pressure differential is reversed. If at this stage the obstruction to the ostium is overcome fresh blood will flow out of the sinus cavity into the nose.

Obstructive sinusitis of ascent occurs when a ball- or flutter-valve in the sinus cavity itself is near the ostium. This allows the free passage of air into the sinus during descent but obstructs its outward flow when ascent begins, presenting equalisation of the pressures on either side of the ostium.

CLINICAL FEATURES

Sinus barotrauma usually presents as a tightness, pressure sensation or pain sited over the affected sinus. It is common on descent, and is aggravated by further descent, and relieved on ascent. The pain may persist in a much reduced form for a few hours. On ascent blood may be noticed in the face mask, arising from the nostril on the affected side.

Occasional variations in the above clinical picture are seen. Sometimes pain will increase with ascent. If ascent is rapid, epistaxis may be the sole symptom.

RESULTS

Fifty consecutive cases in divers of barotrauma affecting the sinuses, are documented.

ONSET

The symptoms developed during or immediately after descent in 34 cases. They developed during or immediately after ascent in 16. The mean interval from the commencement of the dive to the onset of symptoms was 7.6 minutes in descent barotrauma and 20 minutes in ascent barotrauma. In 15 subjects symptoms developed in the first minute. The mean interval above was disproportionately prolonged because of a skewed deviation, as some divers developed the barotrauma symptoms after a series of descents.

<table>
<thead>
<tr>
<th></th>
<th>Interval between commencement of dive and onset of symptoms</th>
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<tbody>
<tr>
<td>DESCENT</td>
<td>68% 7.6 minutes</td>
</tr>
<tr>
<td>ASCENT</td>
<td>32% 20 minutes</td>
</tr>
</tbody>
</table>

PAIN

Pain was the predominant symptom, being present in all cases of descent and in three quarters of ascent barotraumas. It was present in the
frontal area of 34 cases, in the ethmoidal in 8, the maxillary in 3 and the upper dental in 1. The latter was verified to be of sinus aetiology by the absence of any relevant dental pathology or gross radiological anomaly in the adjoining maxillary sinus. Thus the following clinical distribution was noted:

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>FRONTAL</td>
<td>68%</td>
</tr>
<tr>
<td>ETHMOIDAL</td>
<td>16%</td>
</tr>
<tr>
<td>MAXILLARY</td>
<td>8%</td>
</tr>
<tr>
<td>UNSPECIFIED</td>
<td>8%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

**EPISTAXIS**

This was the second commonest symptom, occurring in 19 cases (58%). It was rarely more than an incidental observation and never very severe. In one quarter of the barotrauma of ascent cases, it was the sole symptom.

**RELEVANT ENT HISTORY**

Patients were questioned regarding ENT symptoms. As the responses were subjective, these were not considered to be necessarily valid. Thirty two per cent gave a history of sinus barotrauma in the past. Fifty percent had a history of recent upper respiratory tract infections e.g. viral, bacterial infections, nasal congestion, sneezing, etc. Fifty per cent also gave a history of intermittent or long term symptoms referable to the upper respiratory tract e.g. nasal and sinus disorders, recurrent infections, hayfever, etc.

A further study is being undertaken to define the relevance of the otorhinolaryngological history.

**ENT EXAMINATION**

Clinical examination of the upper respiratory tract was performed. The abnormalities that were sought include:

a) Changes due to barotrauma affecting the tympanic membrane.

b) Nasal abnormalities including septal deflection, mucosal changes, the presence of polyps or abnormal secretions, etc.

c) Tenderness of the sinus on palpation.

Abnormalities were observed as follows:

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<tbody>
<tr>
<td>EARS</td>
<td>NASAL</td>
<td>SINUS</td>
</tr>
<tr>
<td>48%</td>
<td>24%</td>
<td>34%</td>
</tr>
</tbody>
</table>

As in the case of the ENT history, these findings are being studied in another series to define their relevance.

**RADIOLOGY**

Radiological examination of the sinuses was performed within 24 hours in only 43 of the 50 cases. Films were examined by the Radiological Consultants to the Royal Australian Navy. Films were taken with the subject
upright in the postero-anterior, lateral and submento-vertical positions. The abnormalities were classified as: mucosal thickening, gross mucosal thickening with opacity of the sinus, and fluid levels. The results were as follows:

<table>
<thead>
<tr>
<th></th>
<th>ABNORMAL</th>
<th>NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCENT</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>ASCENT</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>34</td>
<td>9</td>
</tr>
</tbody>
</table>

Thus 79% of cases examined radiologically showed sinus anomalies. An observation, which has been recorded but not previously verified, was the distribution and severity of abnormalities. In the following tables, only the most extensive lesion is recorded e.g. if there is a fluid level in the left maxillary sinus and mucosal thickening in the right, only the fluid level would be noted.

<table>
<thead>
<tr>
<th></th>
<th>FRONTAL</th>
<th>ETHMOIDAL</th>
<th>MAXILLARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUCOSAL THICKENING</td>
<td>21%</td>
<td>14%</td>
<td>40%</td>
</tr>
<tr>
<td>GROSS MUCOSAL THICKENING</td>
<td>2%</td>
<td>5%</td>
<td>28%</td>
</tr>
<tr>
<td>FLUID LEVEL</td>
<td>-</td>
<td>-</td>
<td>12%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>23%</td>
<td>19%</td>
<td>80%</td>
</tr>
</tbody>
</table>

In order to verify these findings, the films were then viewed independently by a Consultant Otorhinolaryngologist familiar with sinus barotrauma in divers. No information on diving or medical history was supplied and the Radiologist's results were not made available to him. The results were tabulated from 34 sinus X-ray investigations - 9 being omitted for technical reasons or because they required further X-ray studies. Eighty four percent, 28 of the 34 cases, had sinus abnormalities on X-ray. Of these cases 74% had maxillary involvement, 24% had frontal and 15% ethmoidal.

<table>
<thead>
<tr>
<th></th>
<th>FRONTAL</th>
<th>ETHMOIDAL</th>
<th>MAXILLARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUCOSAL THICKENING</td>
<td>18%</td>
<td>12%</td>
<td>50%</td>
</tr>
<tr>
<td>GROSS MUCOSAL THICKENING</td>
<td>6%</td>
<td>3%</td>
<td>12%</td>
</tr>
<tr>
<td>FLUID LEVEL</td>
<td>-</td>
<td>-</td>
<td>12%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>24%</td>
<td>15%</td>
<td>74%</td>
</tr>
</tbody>
</table>
Although most of the cases showed only mucosal thickening, 12% had a fluid level and an intermediate number had gross mucosal thickening to the stage of causing a total or almost total sinus opacity.

TREATMENT

Most cases required no treatment. Those few that did responded rapidly to the routine use of nasal decongestants only. Only occasionally were antibiotics indicated. It was noteworthy that neither sinus lavage nor surgery were required in any case.

SUMMARY

Sinus barotrauma is a common occupational disease of divers, with the incidence of descent barotrauma approximately double that of ascent. Pain chronologically associated with the change of pressure is the most dominant symptom and is seen in 92% of the cases presented for treatment. The majority complain of a frontal distribution of pain, with ethmoidal and maxillary being much less significant. Epistaxis is the second commonest symptom, and may be the sole symptom in some ascent cases.

A history of recent or past sinus barotrauma or upper respiratory tract pathology, is very common. Clinical examination supports the evidence of upper respiratory tract pathology in many cases.

The radiological signs of abnormality were present in over three quarters of the cases examined. Of these the maxillary sinus was affected in most cases, the frontal in approximately one quarter and the ethmoidal in less than a fifth. The pathology was more commonly that of mucosal thickening, but in 12% of cases there was a fluid level. It is noted that although symptoms were predominantly frontal, X-ray changes were most often present in the maxillary sinuses.
REFERENCES


