Use of postmortem radiographs for the investigation of underwater and hyperbaric deaths

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Calder IM. Use of postmortem radiographs for the investigation of underwater and hyperbaric deaths. Undersea Biomed Res 1987; 14(2):113–132.—The use of postmortem radiographs as a useful adjunct in the investigation of hyperbaric and immersion deaths is discussed. This technique enables accurate identification of gas within cavities that otherwise could not be detected at routine autopsy, which may also be artifact. In addition it is possible to define bone lesions that need a histologic diagnosis.

drowning
radiology
hyperbarism
postmortem
diving

The use of postmortem radiographs in all cases of death in unusual circumstances is imperative (1, 2). The original application of x-rays in such investigations may be attributed to the publicity given in 1896 by Schuster after a shooting incident (3). In hyperbaric and diving activities the environment produces radiologically detectable lesions. These may be acute where a pneumothorax develops or bubbles are present in cavities; postmortem artifact must also be considered. It is imperative that accurate identification of dysbaric-related bone lesions is made, not only for medicolegal purposes but to establish a background of information that is valuable in framing future legislation.

For practical purposes a postmortem x-ray is a useful adjunct, especially so in the context of diving accidents where satisfactory autopsy facilities may be deficient. Tomography can be regarded as an interesting research technique available at a few centers (4), and the sophisticated technique of stereoscopic examination of the skull to demonstrate the presence of air in the cranial vessels (5) is also available. However, the presence of air embolism has been shown radiologically antemortem and subsequently demonstrated at autopsy (6). Direct x-ray of the cadaver may not be possible; in such cases suspicious lesions may be dissected out of the body for accurate and controlled x-rays using the technique described by Camps (7,74). Finally, confounding factors in radiologic techniques may cause difficulty in interpretation, usually due
to variation in film density and the difficulty of accurate positioning of the body due to rigor mortis.

Autopsy diagnosis of gas in tissue is technically difficult, but radiology offers a useful additional dimension. Nevertheless, gas artifacts may occur from manipulation of viscera (8), although it has been shown that anaerobic organisms may produce intravascular gas within 1 to 4 h, given the right conditions (9). It has been suggested (5) that this condition may be eliminated or reduced by examination within a short time of death, but this is not always practicable, and postmortem fermentation can be excluded by careful dissection and bacterial culture.

Although drowning in fresh bodies does not usually present a difficult diagnostic problem, this nevertheless must be viewed in the context of ideal situations investigated by experienced pathologists; but even here it may be difficult to establish such changes on morbid anatomic criteria (7:77).

The use of postmortem radiography has been described extensively in the context of forensic medicine (10, 11) but little in relation to underwater accidents. Nevertheless, where the technique has been available whole body postmortem x-ray has proved to be of value in the investigation of underwater accidents involving professional divers, not only in identifying suspicious bone lesions (dysbaric osteonecrosis) but acute changes developing as a result of hyperbaric and immersion effects. The importance of chest radiographs in near drowning and drowning situations has been described extensively (12) and subsequently reviewed in (13) where special emphasis is placed on the detection of sand in the larynx and tracheobronchial tree.

MATERIALS AND METHODS

In 33 fatal accidents involving divers (Table 1), radiographs were available. However, inasmuch as the examining centers were scattered throughout the world, technical standard varied. All included thorax, but some additional radiographs were made of skull, abdomen, and upper and lower limbs. Skull radiographs were performed in cases of suspected head injury. Long bones and joints were routinely examined whenever possible to identify areas of osteonecrosis. In 8 (25%) of the cases, antemortem radiographs were available from the Medical Research Council Decompression Sickness Registry (MRCDSR) at Newcastle-upon-Tyne as part of a long-term survey of osteonecrosis, but these were confined to long bones.

Only basic radiographic techniques were used and no sophisticated methods were possible. All examinations were performed in the horizontal plane, with the attendant complication of difficult positioning due to rigor mortis. Except in 2 cases, portable apparatus was used. Radiography, with two exceptions, was conducted immediately before autopsy after removal of the diving suit, which formed part of the investigation profile.

After death, the cadavers were refrigerated at +4°C while awaiting autopsy. The environmental temperature shown in column A of Table 1 was usually favorable for preservation during the period between death and refrigeration. The time interval ranged between 1 and 2 h, up to 18 h (mean 7.5 h) (column B). Of all these cases, 9 had been evacuated by helicopter flying at low level (under 600 m).
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Ref</th>
<th>Age</th>
<th>M</th>
<th>Skull</th>
<th>Chest</th>
<th>Upper Limbs</th>
<th>Lower Limbs</th>
<th>Abdomen</th>
<th>History</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WH</td>
<td>23</td>
<td>10</td>
<td>—</td>
<td>Lung cysts</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Scuba diver, surfaced rapidly</td>
<td>6</td>
<td>12</td>
<td>48 h</td>
</tr>
<tr>
<td>2</td>
<td>KDF</td>
<td>28</td>
<td>70</td>
<td>—</td>
<td>Gas both atria, major vessels axil arts</td>
<td>Gas in arts veins, Fig. 11</td>
<td>Gas in vessels, joint cavities knees, Fig 9</td>
<td>Gas in large vessels</td>
<td>Saturation diver; body recovered into bell and slowly decompressed on surface</td>
<td>5</td>
<td>8</td>
<td>36 h</td>
</tr>
<tr>
<td>3</td>
<td>GLM</td>
<td>27</td>
<td>80</td>
<td>—</td>
<td>Gas in vents, aorta and subclav vessels</td>
<td>Gas in major vessels</td>
<td>Superficial vessels contain gas</td>
<td>Gas vessels</td>
<td>Saturation for 5 d; problem on returning to bell; collapsed; resuscitation but dead after 1 h</td>
<td>5</td>
<td>12</td>
<td>24 h</td>
</tr>
<tr>
<td>4</td>
<td>RGK</td>
<td>39</td>
<td>10</td>
<td>—</td>
<td>Salt water drowning</td>
<td>NAD</td>
<td>Hips show prog lesions from antemortem x-ray provided, Fig 10</td>
<td>—</td>
<td>Scuba diver working as fisherman; dived and drowned; probably ran out of gas</td>
<td>6</td>
<td>8</td>
<td>18 h</td>
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<tr>
<td>5</td>
<td>ADS</td>
<td>23</td>
<td>20</td>
<td>—</td>
<td>Edema, Fig 5</td>
<td>NAD</td>
<td>NAD</td>
<td>—</td>
<td>Scuba diver, lost face mask; attempted resuscitation for 1 h</td>
<td>3</td>
<td>4</td>
<td>36 h</td>
</tr>
<tr>
<td>6</td>
<td>GS</td>
<td>33</td>
<td>15</td>
<td>—</td>
<td>Lung fields show gen inc dens with pneumo-pericardium, Fig 6</td>
<td>Gas large vessels</td>
<td>NAD</td>
<td>Gas distending stomach</td>
<td>Scuba diver, disappeared after short excursion with coder</td>
<td>10</td>
<td>6</td>
<td>18 h</td>
</tr>
<tr>
<td>7</td>
<td>RT</td>
<td>26</td>
<td>5</td>
<td>NAD</td>
<td>Salt water drowning, Fig 8</td>
<td>NAD</td>
<td>NAD</td>
<td>—</td>
<td>Scuba diver struck by propeller of ship</td>
<td>6</td>
<td>4</td>
<td>72 h</td>
</tr>
<tr>
<td>Case No.</td>
<td>Ref</td>
<td>Age</td>
<td>Depth, M</td>
<td>Skull</td>
<td>Chest</td>
<td>Upper Limbs</td>
<td>Lower Limbs</td>
<td>Abdomen</td>
<td>History</td>
<td>A</td>
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<tr>
<td>8</td>
<td>ML</td>
<td>32</td>
<td>65</td>
<td></td>
<td>—</td>
<td>NAD</td>
<td>NAD</td>
<td>—</td>
<td>Disappeared from end of umbilical; decomposed body recovered 2 wk later</td>
<td>NK</td>
<td>—</td>
<td>2 wk</td>
</tr>
<tr>
<td>9</td>
<td>AKB</td>
<td>27</td>
<td>3</td>
<td>—</td>
<td>Minimal edema suggesting asphyxia</td>
<td>NAD</td>
<td>NAD</td>
<td>—</td>
<td>Wrong gas mixture in filling of bottles</td>
<td>27</td>
<td>3</td>
<td>4 d</td>
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<tr>
<td>10</td>
<td>GZ</td>
<td>23</td>
<td>3</td>
<td>—</td>
<td>—</td>
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</tr>
<tr>
<td>11</td>
<td>MUL</td>
<td>25</td>
<td>3</td>
<td>—</td>
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<tr>
<td>12</td>
<td>PLY</td>
<td>21</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
</tr>
<tr>
<td>13</td>
<td>PM</td>
<td>32</td>
<td>35</td>
<td>—</td>
<td>Gas trapping in stomach, fluffy opacities both lungs; confluent in right lower zone, drowning; gas in aorta and arteries, Fig 3</td>
<td>No bone damage; bubble in arteries</td>
<td>—</td>
<td>—</td>
<td>Air diver got into difficulties</td>
<td>6</td>
<td>12</td>
<td>2.5 d</td>
</tr>
<tr>
<td>14</td>
<td>AG</td>
<td>38</td>
<td>30</td>
<td>—</td>
<td>Lung fields show an inc in den; pneumatization in lower zone &amp; costophrenic angle; pneumopericardium; locules air in pericardium</td>
<td>NAD</td>
<td>—</td>
<td>—</td>
<td>Air diver lost mask and body recovered within 10 min</td>
<td>2</td>
<td>NIL</td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>ALM</td>
<td>21</td>
<td>10</td>
<td>—</td>
<td>Inhalation of water; not suggestive absorption, Fig 7</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Drowned scuba diver from quarry, fresh water</td>
<td>10</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>16</td>
<td>BS</td>
<td>39</td>
<td>8</td>
<td>—</td>
<td>Marked edema through lung fields</td>
<td>NAD</td>
<td>—</td>
<td>—</td>
<td>Shallow water scuba diver working in the temperature of 8°C, hypothermia</td>
<td>5</td>
<td>6</td>
<td>12</td>
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<tr>
<td>No.</td>
<td>Last</td>
<td>First</td>
<td>Age</td>
<td>Sex</td>
<td>Cause of Death</td>
<td>Pathology</td>
<td>Method of Grading</td>
<td></td>
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<tr>
<td>17</td>
<td>JKD</td>
<td>26</td>
<td>80</td>
<td></td>
<td>Chest pain during surfacing from &quot;bounce&quot; dive; no bell available</td>
<td>Clouding both lungs; pulmonary edema of drowning; fractures of ribs; surgical emphysema right side and a left pneumothorax; gas in the left atrium; gas in axillary and right brachial arts commo carotid arts as film, Fig 1</td>
<td>2 $^{12h}$ 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>18</td>
<td>AMcG</td>
<td>31</td>
<td>30</td>
<td></td>
<td>Unconscious on surfacing; recompressed to 50 m on air; died 2 d later.</td>
<td>Lungs aerated</td>
<td>NAD NAD —</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>19</td>
<td>BMS</td>
<td>25</td>
<td>10</td>
<td></td>
<td>Working on maintenance for DP vessel; caught in thruster</td>
<td>Cloud both lungs suggest pulmonary edema</td>
<td>No evidence of bone lesions NAD —</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20</td>
<td>KGA</td>
<td>27</td>
<td>20</td>
<td></td>
<td>Working in sea water for 90 min on air; technical problem led to sudden surfacing; certified dead</td>
<td>Cloud lung folds compact salt water drowning; gas in atra and main arteries.</td>
<td>NAD NAD —</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>21</td>
<td>BM</td>
<td>28</td>
<td>103</td>
<td></td>
<td>Blow up from bottom due to technical fault</td>
<td>Left pneumothorax surg emphysema; vessels filled gas</td>
<td>Gas periph vessels arms; opacity shaft left humerus (confirmed as enchondroma on histology) Vessels filled gas to periphery</td>
<td>5 $^{12h}$ 36</td>
<td></td>
<td></td>
<td></td>
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</table>
I. M. CALDER

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Ref</th>
<th>Age</th>
<th>M</th>
<th>Death</th>
<th>Duration</th>
<th>History</th>
<th>Location</th>
<th>Findings</th>
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<tbody>
<tr>
<td>22</td>
<td>AD</td>
<td>36</td>
<td>25</td>
<td></td>
<td>10</td>
<td>Fresh water scuba diving; believed to have panicked; dive stopped of 10 min; rapid recovery of body surface.</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>23</td>
<td>DNQ</td>
<td>31</td>
<td>15</td>
<td></td>
<td>NAD</td>
<td>Gas in large bowel</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>24</td>
<td>DV</td>
<td>29</td>
<td>4</td>
<td></td>
<td>NAD</td>
<td>Edema lungs</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>25</td>
<td>MCK</td>
<td>38</td>
<td>4</td>
<td></td>
<td>NAD</td>
<td>Lungs aerated</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>26</td>
<td>TB</td>
<td>32</td>
<td>65</td>
<td></td>
<td>NAD</td>
<td>Edema lungs; chamber; aortic arch, axillary arch, and carotid arteries</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>27</td>
<td>RLC</td>
<td>23</td>
<td>3</td>
<td></td>
<td>NAD</td>
<td>Patches edema bases</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td>28</td>
<td>MAA</td>
<td>25</td>
<td>12</td>
<td></td>
<td>NAD</td>
<td>Cloudy lungs; characteristic salt-water drowning.</td>
<td>NAD</td>
<td>NAD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pulmonary edema suggestive of drowning</td>
<td>NAD</td>
<td>NAD</td>
<td>Experienced diver; too many weights and became negatively buoyant</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>29 KGA</td>
<td>27</td>
<td>20</td>
<td>Right pneumothorax, surgical emphysema; gas aortic arch, and atria, axillary and brachial arteries.</td>
<td>Beading of gas in peripheral arteries and veins</td>
<td>NAD</td>
<td>Gas in aorta and major branches</td>
<td>Rapidly brought to surface without use of bell; collapsed within few minutes</td>
<td></td>
</tr>
<tr>
<td>30 WAN</td>
<td>37</td>
<td>85</td>
<td>Displac mediastinum left, gas aorta and major vessels; both atria contain gas</td>
<td>Walls vessels outlined by lumina filled with gas</td>
<td>Gas in all major vessels</td>
<td>All vessels contain gas and distention of stomach by gas</td>
<td>Umbilical cut at depth; found dead on sea bed</td>
<td></td>
</tr>
<tr>
<td>31 MB</td>
<td>24</td>
<td>105</td>
<td>Edema; characteristic salt water drowning, Fig 4</td>
<td>NAD</td>
<td>NAD</td>
<td>No gas visualized in the abdomen</td>
<td>Hard hat diver; air line fouled on wreckage</td>
<td></td>
</tr>
<tr>
<td>32 GH</td>
<td>43</td>
<td>7</td>
<td>General fluffy appearance lungs; major &amp; minor vessels &amp; atria show gas cavities</td>
<td>Multiple bubbles within vessels</td>
<td>Gas within vessels, Fig 13</td>
<td>Gas in all vessels; stomach dilated by gas</td>
<td>Anoxic anoxemia</td>
<td></td>
</tr>
<tr>
<td>33 PK</td>
<td>26</td>
<td>330</td>
<td></td>
<td></td>
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</tbody>
</table>

NB: (A) Approximate air temperature at time of death (centigrade)
(B) Time interval between death and refrigeration, and whether helicopter (H) evacuation.
(C) Time interval between death and PM.
RESULTS

The results are consolidated in Table 1 and are based on radiologists’ and clinicians’ objective opinions of the x-ray plates and the history of the accident. Radiographs of the thorax were available in 33 cases, 31 of which included shoulder joints and adjacent blood vessels. One radiograph (case 21) included radius and ulna, and 28 included hip and knee joints. In 12 cases there was sufficient radiographic coverage to allow comment to be made on the abdomen. Five radiographs were performed on the skull.

Thorax

The radiograph of the thorax is a very useful adjuvant in resolving complicated clinicopathologic problems such as drowning, pneumothorax, or barotrauma.

Gas trapping

Figure 1 (case 17) was from a bounce dive to 80 m in which no diving bell was available. The radiograph shows pulmonary edema with surgical emphysema and a left pneumothorax. Gas can also be visualized in the aorta, right and left atria, and blood vessels of the upper part of the body.

Air trapping may also give rise to lung cysts within the parenchyma (Fig. 2, case 1), which were not evident at dissection. Artifact due to gas and air trapping are an ever-present problem; Figure 3 (case 13) shows air trapping in the stomach, which causes difficulty in visualizing the cardiac outline. There are however opacities in the lung fields with appearances consistent with drowning.

Drowning

Figure 4 (case 32) shows pulmonary edema associated with salt water drowning. Such appearances may be modified when resuscitation has been applied as shown in Fig. 5 (case 5) which was substantiated by clinical history.

Drowning may affect only parts of the lung shown in Fig. 6 (case 6). Variation in density of the chest films may result from the type of fluid inhaled. This is illustrated in Fig. 7 (case 15) and Fig. 8 (case 7). In the former, which was fresh water drowning, the changes are much more marked than in the latter from a salt water immersion, suggesting that water has been inhaled but not absorbed.

Bones and joints

Radiographs were obtained bilaterally on 28 upper and 25 lower limbs. The presence of gas was a constant feature in vessels. It was also identified in joint spaces, shown in Fig. 9 (case 2). Only one case of dysbaric osteonecrosis was seen on radiographs and that had been diagnosed clinically. The ante- and postmortem radiographs are shown in Fig. 10 (case 4). Figure 11 (case 2) shows gas filling both arteries and veins, with the vessel walls outlined. The vessels were not always completely filled with gas, as shown in Fig. 12 (case 26) when gas was present only in the proximal parts. In Fig. 13 (case 33) gas is seen only in the superficial vessels. Divers who died in
saturation environments and were slowly released to atmospheric pressure showed a "beading" appearance within the lumen, Fig. 14 (case 30).

DISCUSSION

The use of radiographs in the forensic autopsy have been extensively reviewed (14, 15) but the application of the technique to a specific group of workers has not yet been reported. This series represent a group of cases of underwater deaths in which it has been possible to radiologically identify distinct features due to their often unique underwater environment.

From the practical standpoint the precise diagnosis of drowning can be difficult. Death may occur after the victim has been recovered alive from the water, at any time from minutes to several days (16). The use of radiology may be a useful method of assessment of the status of the patient. In examination of these examples of known drownings there is a wide range of appearances, which without accurate clinical data are liable to misinterpretation.
Figure 1 shows pulmonary edema with surgical emphysema and pneumothorax on the left side. In addition, there is gas in the aorta, right and left atria, as well as in the blood vessels of the upper part of the body. Such findings are liable to be interpreted as artifact or completely missed once autopsy has commenced. In this case of rapid ascent from depth, air embolism developed with consequent unconsciousness, lung collapse, and drowning in sea water on the surface. This contrasts with the limited appearances in Fig. 4 (case 32) when the only abnormality is pulmonary edema in salt water drowning in a shallow diving excursion.

The picture of edema may be modified by the action of artificial respiration as in the case of known drowning in Fig. 5 (case 5). In this case the edema is not so intense, although clinically considerable amounts of sea water were known to have been inhaled. The effects of the inhalation of water may not be diffuse. Part of the lung may be preserved as shown in Fig. 6 (case 6) especially in the costophrenic angles and again may be modified by resuscitation.

Generalized increase in lung density throughout a chest film may occur as the result of the type of fluid inhaled and be correlated with the circumstances. However, this effect is not as clearly distinguishable in man as in animal experiments (16). The pattern also varies if viscous material is absorbed (17).

Hunter and Whitehouse (18) noted the importance of x-rays in cases where the victim was recovered alive but died minutes or days later due to "secondary drowning." Fuller (19) found this in 19 out of 77 cases of near drowning. Preliminary radiology may provide a useful method of assessing the status of the patient and give support to subsequent investigation or litigation.
Fig. 3. Air and gas trapping in stomach. Numerous fluffy opacities throughout both lung fields, becoming confluent in right lower zone. Gas in aortic arch and axillary arteries (case 13).

There is no doubt that inhalation of salt water gives markedly different effects from that of fresh water. Animal experimentation has shown (20) that inhalation of hypertonic sea water results in water passing from the blood to alveoli together with transfer of electrolyte. Rapid hemoconcentration occurs, resulting in pulmonary edema. Conversely, inhalation of fresh water in experimental animals results in rapid absorption into the circulation, with hemodilution and hemolysis of red cells, although this has not been supported in human investigations (21).

Figure 7 (case 15) shows grosser changes than Fig. 8 (case 7), which suggests that more water was inhaled but not absorbed. This finding is in agreement with the clinical situation, Fig. 7 (case 15), in which inhalation of fresh water gives rise to transcapillary passage of water into the alveoli, suggesting more severe damage.

Trapping of air in the lung can result in barotrauma and was first considered by Case and Haldane (22). However, it has been observed (23, 24) that damage may be localized and result in cyst formation as observed in Fig. 2 (case 1), but this could not be identified at autopsy.
In similar context, air or gas may be trapped in the stomach, making it difficult to view the cardiac outline, as shown in Fig. 3 (case 13). However, numerous fluffy opacities throughout both lung fields become confluent, especially in the right lower zone, which consistent with drowning. Gas is present in the vascular system, which complicates the physiologic situation, and results from rapid ascent from depth and subsequent drowning.

The diagnosis of pneumothorax should not produce major problems for pathologists if the technique used is correct (25). However, in Fig. 1 (case 17) it is possible to visualize a pneumothorax as well as areas of surgical emphysema and gas in blood vessels, an observation that could not be made easily during dissection and which substantiates a diagnosis of barotrauma.

Radiologic detection of free gas in tissues is a common finding of little clinical significance according to Ferris and Engel (26). However, gas may accumulate in cavities and spaces in joints. This is shown in Fig. 9, but is of little significance because such observations have been reported in routine x-rays in divers (27).

Postmortem radiographs of limbs are essential to identify bone lesions as well as soft tissues. In the United Kingdom, bone lesions resulting from dysbarism have usually been identified during life by routine screening in medical examinations.
required by Diving Regulations. This information is recorded centrally at the MRCDSR. Ideally, such information would be available before autopsy begins, but if it is not, suspicious areas can be identified from whole body radiographs before more detailed examination, as suggested by Camps (7). The use of this technique is shown in Fig. 10 (case 4) where a lesion in the hip is identified and the progression of the changes are highlighted; the only such case identified in the series. However, a shaft lesion was identified on a routine antemortem radiograph, but histology proved this to be an enchondroma.

Radiographs of limb soft tissues are of value in visualizing the effects of a hyperbaric environment on blood vessels with respect to the presence of gas and its interpretation in the correct clinical context. Gas in peripheral vessels is essentially due to local effervescence from blood rather than embolism and this is readily identified in both arteries and veins.

In 19 cases of saturation divers examined, arteries and veins of limbs showed proximal filling with gas, as illustrated in Fig. 11 (case 2). However, distally, only the veins have filled, illustrated by Fig. 12 (case 26). Slow release of environmental pressure after death gives the picture of (‘‘beading’’ within the vessels, shown in Fig. 14 (case 30), suggesting a more local release of gas.
These observations are especially relevant for the selection of appropriate blocks for histologic examination. Richter and Loblich (28) have suggested that this technique may be extended to the use of electron microscopy, a technique that can be more definitive in establishing the ante- or postmortem origin of bubbles. Nevertheless, the significance of all bubbles has to be evaluated carefully and considered along with the available clinicopathologic data, or it could be regarded as artifact (29).

Johnson (30) demonstrated the use of radiology before exploration of vessels in which mercury had been injected; however, tomography may give useful results in more complicated cases (31).

In cases used as examples, postmortem artifact was minimal; these cases were mainly from the northern North Sea where air and water temperatures were low and recovery, refrigeration, and autopsy rapid.
POSTMORTEM RADIOGRAPHS

Fig. 7. Inhalation of water without absorption, cf. Fig. 6 (case 15).

Fig. 8. Salt water drowning, cf. Fig. 5 (case 7).
Fig. 9. Gas within joint space of the knee joint (case 2).

Fig. 10. Radiographs of hip joint showing progression of bone changes from antemortem appearances (case 4).
Fig. 11. Gas in superficial and deep vessels of leg. Some irregularity of vessels, suggesting partial obstruction of femoral (case 2).

Fig. 12. Gas in proximal arteries and veins (case 2b).
Fig. 13. Gas in veins (case 33).

Fig. 14. Beading of vessels suggesting small quantities of gas released locally in partial saturation diving situation (case 30).
CONCLUSION

This paper emphasizes the use of postmortem radiographs in specialized investigations. In the context of underwater accidents it can give useful confirmatory evidence of lung damage as well as on the problems of water inhalation. In addition, the technique is critical in visualizing the presence of gas in vessels and cavities. It is important however that such findings are interpreted correctly in accident situations.

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