PRELIMINARY OBSERVATIONS ON THE OXYGEN AND CARBON DIOXIDE GAS TENSIONS IN THE KNEE-JOINT IN NORMAL AND PATHOLOGICAL CONDITIONS

BY OSWALD A. SAVAGE, AND H. J. TAYLOR,

The injection method of estimating the carbon dioxide and oxygen tissue gas tensions has been extensively used for observations in the pleural cavity, the peritoneal cavity, the bladder, the washed-out stomach and intestine, the subcutaneous tissues and the body fluids. The principle of the method is that air, nitrogen or a mixture of oxygen, carbon dioxide and nitrogen is injected into the tissue or part whose oxygen and carbon dioxide tension it is desired to measure. The gas is left until in equilibrium with the tissue gases and a sample is then removed and analysed. The subject has been reviewed by J. Argyll Campbell (1931). It cannot be said that the presence of the injected gas is usually normal, but injection of gas into the pleural cavity is a routine method of treating tuberculosis of the lung and the injection of oxygen into the sheath of the nerve is a method of treating sciatica. We can find no data with regard to gas tensions in joints. It is from this point of view that we have made measurements of gas tensions in joints, both normal and diseased.

Previously gas has been injected into joints with two objects in view:

(a) For Diagnostic Purposes.—Inflation of the joint, it is claimed, gives clearer radiographs and thus facilitates examination. It has been used by many authors, notably Terracol and Colaneri (1920), Prat (1920), Kleinberg (1921), Kasin (1922), Balensweig (1924), Cattaneo (1923), Bernstein and Arens (1926), Werndorff (1929), Ulrichs (1930), Bircher (1931), Purves and Bilcliffe (1924), Oberhalzer (1933-34), Junghagen (1933), Schrum (1933), Bircher and Oberhalzer (1934), Simon, Hamilton and
For Therapeutic Purposes.—The inflation of a joint has been used by many workers as a therapeutic measure. The injected gas might be expected to exert a cushioning effect. Fluid in a joint exerts a hydraulic action with the slightest movement, and this tends to stretch the joint capsule. Gas, being compressible, will prevent this; it will also tend to separate inflamed parts, and thus prevent adhesions. Injection of oxygen into a joint also tends to inhibit the growth of bacteria, such as gonococcus, which require a low oxygen tension for growth. The injection of gas with this object in view has been widely used, notably by Rost (1920-21), Raymond (1923), Purves and Bickleffe (1924), Caccia (1927), Reich (1927), Rechtman (1929), Porter and Rucker (1929), Henson (1930, 1936), Mondor (1931), Vilar (1931), and Vohlman (1936).

Technique of Gas Injection

The knee-joint was the only one used in this work. The prepared knee was flexed at 45° and the site of entry of the needle infiltrated down to the capsule with ½ per cent. of procaine hydrochloride solution. The best site was found to be in the recess between the lower and outer edge of the patella and the lateral condyle of the tibia. The gas was injected through a Clive Rivière No. 1 needle attached to a Heaf’s pneumothorax apparatus. The chamber of the latter was filled from a cylinder, the needle inserted into position, and gentle pressure applied by hand to the top of the chamber. Before commencing to inject the gas a pressure reading was taken on the manometer of the apparatus, and on no occasion was there found to be either a positive or a negative pressure inside the joint which could be recorded on a scale reading to 1-0 cm. of water, nor was any such pressure obtained with small movements of the joint. It was usually found that before any appreciable amount of gas could be forced into the joint the pressure had to be raised to above 25 cm. of water. Gas could then often be heard bubbling into the joint. Injection may be carried to the point at which discomfort begins to be felt. The joint is then distended with gas, and it was usually found that about 300 c.c. could be injected.
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without causing undue pain. The first few times this technique was carried out the presence of gas was confirmed radiologically (see Fig. 1), but as it was always obviously present on palpation this was dispensed with as giving no further information. Gas could usually be felt in the joint for at least four days. Difficulty was experienced with cases of osteo-arthritis. Little gas could be injected into these joints, making the taking of subsequent samples for analysis most difficult; in fact, it was only possible to obtain a sample of gas for this purpose from one out of six cases. Gas for analysis was obtained in a syringe filled with lightly acidified 80 per cent. glycerine. The needle of this syringe was inserted into the joint at the site used for the injection of the gas after local anaesthesia as before. The capsule was compressed by hand and the gas bubbled out into the syringe.

FIG. 1.—X-RAY PHOTOGRAPH OF KNEE-JOINT AFTER GAS HAS BEEN INJECTED.
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The gas sample was analysed by the method described by Campbell and Taylor (1935). A note is taken of the barometric pressure, since this is necessary in calculating the gas tensions. No patient complained of discomfort either during or after gas injection.

RESULTS

No data are available on the normal gas tensions in the knee-joint, and it was therefore necessary for this purpose to carry out some determinations on normal joints.

Case 1.—Man, aged twenty-four. Right knee external semilunar cartilage removed, right knee injected. Gas tensions: \( \text{CO}_2 \), 31 mm. Hg; \( \text {O}_2 \), 33 mm. Hg.

Case 2.—Man, aged thirty-one. Gas tensions: \( \text{CO}_2 \), 29 mm. Hg; \( \text {O}_2 \), 34 mm. Hg. These two results are in good agreement, but before these figures are accepted as the correct ones we consider that further experiments are desirable.

Case 3.—In a case of traumatic effusion into the knee-joint which had subsequently cleared up it was found that the gas tensions were: \( \text{CO}_2 \), 40 mm. Hg; and \( \text {O}_2 \), 16 mm. Hg. This oxygen tension was much lower than that in the normal joints 1 and 2, and it is obvious that the case cannot be taken as a normal, although recovery appeared to be complete.

Pathological Conditions

Case 4.—Rheumatoid arthritis: Acute rheumatoid arthritis. Male, aged eighteen. Duration one month; marked swelling of the peripheral joints; fever 99° to 102° F.; a typical example of rheumatoid arthritis. Gas injected into the left knee. (a) Arthrotomy and lavage performed three days later, and the joints seen to be full of glairy mucoid material which was squeezed out. Synovial membrane hyperaemic. One month later right knee injected with gas (b); ten days later this was repeated (c). Gas tensions: (a) \( \text{CO}_2 \), 18-2 mm. Hg; \( \text {O}_2 \), 56 mm. Hg. (b) \( \text{CO}_2 \), 15 mm. Hg; \( \text {O}_2 \), 62 mm. Hg. (c) \( \text{CO}_2 \), 19 mm. Hg; \( \text {O}_2 \), 52 mm. Hg.

Case 5.—Acute rheumatoid arthritis. Male, aged nineteen. Duration three months; increasing swelling of hands, feet and knees; fever to 101° F.; marked muscle wasting. Gas injected into the left knee. Gas tensions: \( \text{CO}_2 \), 20 mm. Hg; \( \text {O}_2 \), 55 mm. Hg.

Case 6.—Rheumatoid arthritis subacute. Male, aged fifty-nine. History of increasing pain and stiffness in hands, wrists and knees for a year. Effusion into both knee-joints; swollen interphalangeal joints. Considerable wasting of interossei and quadriceps muscles. Slight loss of weight. The condition was still active clinically and the sedimentation rate was 62 mm. Westergren after 1 hour. Both knee-joints injected with gas. Gas tensions: Left knee: \( \text{CO}_2 \), 48 mm. Hg; \( \text {O}_2 \), 20 mm. Hg. Right knee: \( \text{CO}_2 \), 50 mm. Hg; \( \text {O}_2 \), 15 mm. Hg.

Case 7.—Rheumatoid arthritis subacute. Male, aged forty-five. For seven months increasing stiffness and swelling of hands and feet. Loss of weight and malaise. Muscle wasting marked. Sedimentation
rate, 22. Right knee injected. Gas tensions: CO₂, 45 mm. Hg; O₂, 12 mm. Hg.

Case 8.—Rheumatoid arthritis subacute. Male, aged twenty-eight. History of increasing stiffness and swelling of hands and feet for three months. Loss of weight. Fever 100° F. occasionally. Muscle wasting evident. Sedimentation rate, 57 first hour. Gas tensions: CO₂, 38 mm. Hg; O₂, 30 mm. Hg.

Case 9.—Gonococcal arthritis. Male, aged twenty-five. Gonorrhoea five years before. Painful and swollen right knee for four weeks. Gonococcal fixation test positive in blood. Prostatic bead nil. Right knee injected. Gas tensions: CO₂, 45 mm. Hg; O₂, 9 mm. Hg.

Case 10.—Male, aged twenty-nine. Four months pain and effusion both knees. The patient denied gonorrhoea and the joint fluid gave negative gonococcal fixation tests. The condition was thought to be gonococcal arthritis clinically and an attack of epididymitis occurred while in hospital. After three bouts of artificial fever the condition cleared up. Left knee injected. Gas tensions: CO₂, 30 mm. Hg; O₂, 20 mm. Hg.

Case 11.—Osteo-arthritis. Female, aged sixty-three. Five years pain and swollen knees. Weight 15 stone. B.P. 210/120. Sedimentation rate, 2. Crepitus and limitation of movement of both knees. X-rays show irregularity of joint surfaces and osteophytic outgrowths in both knees. Gas tensions: CO₂, 46 mm. Hg; O₂, 7 mm. Hg.

Case 12.—Male, aged forty-four. Twenty years backache. Marked kyphosis with spinal rigidity. X-rays show calcification of spinal ligaments and obliteration of the sacro-ilial joints. Gas injected into the left knee and samples removed after twenty-four and forty-eight hours. Gas tensions (twenty-four hours): CO₂, 46 mm. Hg; O₂, 12 mm. Hg. Forty-eight hours: CO₂, 42 mm. Hg; O₂, 15 mm. Hg.

These results are summarised in table below.

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<tr>
<th>Diagnosis</th>
<th>O₂</th>
<th>CO₂</th>
</tr>
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<tbody>
<tr>
<td>Rheumatoid arthritis acute</td>
<td>56</td>
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<td>62</td>
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<td>Rheumatoid arthritis acute</td>
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<td>62</td>
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<tr>
<td>Gonococcal arthritis</td>
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</tr>
<tr>
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<tr>
<td>&quot;Normal&quot;</td>
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</tbody>
</table>

Conclusions

The small number of cases reported precludes the drawing of any definite conclusions, but it seems significant to us that in acute rheumatoid arthritis the O₂ tension is higher and the CO₂...
tension lower than normal, as might be expected in an inflammatory condition. We would suggest that the values for the later stages of this disease and in conditions of osteo-arthritis, gonococcal arthritis, spondylitis ankylopoietica, and in traumatic effusion (after the effusion has cleared) suggest some permanent interference with the blood and/or lymph supply to the joint in these cases, as has been shown histologically by Timbrell Fisher. Further work is in progress on this subject.

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