CORNEAL AND CONJUNCTIVAL XYLANTHRACOSIS CAUSED BY CARBON-GAS FROM GENERATORS*†‡

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THESE cases of ocular damage by charcoal were observed during the years of the German occupation of Greece (1941–45), when, owing to the shortage of liquid fuel, almost all internal combustion engines were adapted for operation with coal-gas generators (Fig. 1).

FIG. 1.—Diagram of gas-generator. 1 = metal lid. 2 = aperture of container. 3 = tap with automatic valve. 4 = space ($\frac{1}{3}$ of container) for collecting the gas mixture produced. 5 = pipes for conducting the mixed coal-gas to filters. 6 = space ($\frac{2}{3}$ of container) serving as fuel bed for the charcoal (combustion chambers). 7 = iron chamber with inner wall of firebricks (height: 1.50 m, diameter: 0.70 m) with grate and cinder box at the bottom. 8 = oven with inner covering of firebricks. 9 = hearth, divided into two compartments—an inner one for fuel and an outer one for water.

The water evaporates during the combustion of the fuel in the inner compartment and the steam thus generated envelopes the charcoal above, thus ensuring a slow combustion process.

10 = tank for the water supply of the inner combustion chamber. 11 = smoke escape from hearth. 12 = fan blower. 13 = filter for cleaning the mixed coal gas. 14 = pipe for conducting the generated pure gas to chamber No. 16, *i.e.* between the spark-plug No. 15 and the cylinder No. 17, where ignition of the gas takes place.

The chief fuel for these generators was charcoal, and owing to the high temperature developed the following approximate composition of coal-gas was obtained in Compartment (4) through the distillation process of the charcoal taking place in Compartment (6):

* The term "xylanthracosis" has been coined in accordance with the terminology employed by Duke-Elder (1965) where we find "lithiasis" from Greek "lithos" = stone, "Chalcosis" from Greek "chalkos" = copper, "argyrosis" from Greek "argyros" = silver, "chrysiasis" from Greek "chrysos" = gold, and "siderosis" from Greek "sideros" = iron. "Xylanthracosis" is derived from Greek "xylanthrax" (ξύλανθραξ) = charcoal.

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<i>Component</i>	<i>Percentage per vol.</i>
Nitrogen	55-68
Carbon dioxide	4- 7
Carbon monoxide	22-25
Hydrogen	4-10
Methane	1- 3

Residual quantities of coal-tar, acetone, xylol, etc., are also obtained.

Causes of Accidents

(a) During opening of the valve (11) by means of which the original ignition is achieved and which also permits the burning wood-barks and charcoal to be inspected in the combustion chamber. When the fuel runs low, it is replenished, usually by hand.

(b) When the iron lid of the generator (1) is opened in order to check, through the aperture of container (2), whether there is a sufficient amount of mixed generator-gas in container (4), as well as an adequate amount of charcoal in chamber (6). When required, fresh charcoal is thrown in, usually by hand.

(c) When tap (3) is turned open, to check the power of the generated gas and its ignition.

The clinically most severe accidents were due to the causes listed under (b). When the lid is opened there is as a rule a violent emission of flames, sparks, and fragments of glowing charcoal, residues of coal-tar, etc.

When the pure carbon content of charcoal is not below 65 to 70 per cent. it will combine with the albumen of the tissues, with which it appears to possess considerable chemical affinity. The black colouring particles lie on the surface of the minute charcoal grains and on account of their caustic and astringent properties act upon the cells and intercellular tissues and cause a peculiar purplish-black staining.

Clinical Findings

(1) **Intoxication.**—This is primarily due to carbon monoxide, and is preceded by the well-known preliminary symptoms.

(2) **Burns.**—These are caused chiefly by the heat flash and to a lesser degree by the chemicals expelled. Heat burns are as a rule benign, since the temperature is only moderate, and the chemical components, chiefly carbon monoxide and carbon dioxide, cause only superficial lesions, which are neutralized by the alkaline reaction of the tissues. It is the glowing charcoal particles which penetrate the tissues that may cause severe damage.

(a) *Periocular Burns* (Fig. 2).—First, second and, less frequently, third and fourth degree burns usually around the eye, on the forehead, eyelids, nose, etc. They are generally diffuse with penetration of the tissue by fragments of charcoal and its chemical by-products. On the eyelids this may cause a splitting of the lid margin, leaving a more or less disfiguring scar, without entropion or ectropion.

FIG. 2.—Periocular burns 8 days after accident.

(b) *Burns of the Eye*.—Both the cornea and the conjunctiva may be affected (Fig. 3). The simple impact of a glowing particle on the cornea may cause a loss of glossiness with anaesthesia of the epithelium, which together with Bowman's membrane shows a diffuse haziness. It is sometimes followed by a shedding of the epithelium, but this usually heals quickly with no permanent scar.

FIG. 3.—Diagram showing particles of charcoal lodged in cornea and conjunctiva.

In the conjunctiva a minor lesion with moderate oedema may occur and phlycten-like nodules may form. When charcoal fragments lodge in the tissue, we find, that as well as a very intensive inflammation of the cornea there is usually also a horizontal ulceration extending to the limbus. The conjunctiva shows, mainly in the interpalpebral zone desiccation, a loosening of coherence, and formation of greyish-white vesicles up to lentil-size, covered by epithelium. This is followed by the formation of prominent greyish-white eschars which slough leaving a bleeding surface.

Microscopical Examination

(1) *Conjunctivitis or Keratitis due to Charcoal Grains*.—After initial treatment, *i.e.* after the removal of the charcoal fragments which have penetrated into the eye, minute charcoal grains remain in the affected tissues. For approximately 3 days diffuse black grains may be distinguished; these are round or angular in shape and are embedded in the epithelium of the cornea and in Bowman's membrane, or even more deeply. In the conjunctiva these grains are usually localized under the epithelium or, more rarely, in the episclera. There is also severe inflammation (Figs 4 and 5). After 4 to 11 days some of the charcoal grains disappear as a result of treatment, but others persist. These particles cause some oedema and sloughing, in the course of which most of the retained charcoal grains are also cast off. After this sloughing process the inflammation subsides and healing ensues.

FIG. 4.—Corneal deposit of charcoal after 3 days.

FIG. 5.—Conjunctival deposit of charcoal after 3 days.

(2) *Conjunctival or Corneal Xylanthracosis*.—Simultaneously with the process described above, some black particles may be absorbed by the adjoining cells and intercellular tissues. By the 12th to 16th day the inflammation has almost subsided and the remaining charcoal grains have meanwhile become surrounded by fibrous tissue and have penetrated deeper into the tissues, some having fragmented into even tinier particles. These are then absorbed by the adjoining tissues, which thus acquire a peculiar bluish-pink to black hue. This colouring may penetrate into the deeper layers or may remain nearer the surface.

About the 17th to the 22nd day further irritation and inflammation may be caused by the colouring matter of the absorbed charcoal grains. There is also a tendency for the epithelial cells to slough, whereby the colouring matter is also largely extruded. After 23 to 28 days the peculiar diffuse and punctate purplish-black colouring of the cells and intercellular tissues gradually reappears and this is the phenomenon we have designated "xylanthracosis" (Figs 6 and 7).

FIGS 6 and 7.—Xylanthracosis of the conjunctiva (Fig. 6) and of the cornea (Fig. 7) in the broad (a) and narrow (b) beam of the slit lamp.

After about 2 months this colouring has become more or less permanent—in the conjunctiva chiefly in the connective tissue, and in the cornea chiefly under the epithelium, in Bowman's membrane and the superficial layers of the substantia propria. In favourable conditions the xylanthracosis and the shadowy mottled bluish-pink to black colouring remain, but there is no recurrence of inflammation.

Treatment

As in other cases of irritants and burns of the eyes and periocular regions, the eyelids are everted and the particles removed from the conjunctiva. Drops and

ointment, usually sulphonamide with vitamin A, are applied and parenteral or oral chemotherapy is given until the lesions have healed.

Case Reports

Out of a total of thirteen cases two are selected for detailed description.

Case 1, a man aged 22, after an accident with a faulty gas-generator in a car on November 25, 1941, showed the preliminary symptoms of carbon monoxide poisoning. The periocular regions showed second to fourth degree burns with diffuse penetration by fairly large charcoal fragments, especially on the right forehead and upper eyelid. The eyes were also penetrated by charcoal particles. In the right eye a small charcoal fragment was lodged near the centre of the cornea, another in the conjunctiva towards the temple, and a third one in the lower conjunctival fornix. In the left eye a large fragment was seen near the centre of the cornea, and three or four smaller ones had penetrated the cornea in the region of the interpalpebral aperture. The patient was hospitalized for 21 days. 2 months later a partial symblepharon appeared near the centre of the lower fornix of the right eye.

The visual acuity in the right eye was 5/10, and 8/10 with -2.25 D sph. $+1.25$ D cyl., axis 165° ; and in the left eye 7/10 and 9/10, with -1.5 D sph. $+0.75$ D cyl., axis 130° .

The case was followed up over 2 years; there was no relapse, but the xylanthracosis did not disappear.

Case 2, a woman aged 48, after an accident with a gas-generator at a flour mill, suffered second and third degree burns in the periocular region with dispersed penetration of larger and smaller charcoal fragments, one of which split the edge of the eyelid. The eyes also were penetrated by the charcoal fragments. In the right eye a small fragment lodged in the sclera and cornea, and in the left eye there was a large fragment near the centre of the cornea and two or three fragments in the conjunctiva towards the temple. She remained in hospital for 17 days and was afterwards followed up at infrequent intervals. A very small disfiguring scar remained on the free edge of the upper lid of the left eye.

After 3 months the visual acuity in the right eye was 8/10, and 10/10 with -0.75 D sph., $+0.25$ D cyl., axis 130° ; and in the left eye 4/10, and 8/10 with -1.5 D sph. $+0.75$ D cyl., axis 70° . She has been re-examined twice or three times a year for 6 years. No relapse has occurred.

Summary

In the production and use of generator-gas, accidents giving rise to heat-flash and the expulsion of chemical substances and red-hot charcoal fragments may cause carbon monoxide poisoning and burns and lesions of the conjunctiva, cornea, and periocular region. Microscopical examination has revealed that some of the small black charcoal particles embedded in the eyes may be sloughed off with necrotic tissues. Others may be retained among the cells and in the intercellular tissues, which thereby acquire a peculiar colouration, designated "xylanthracosis" (Ξυλανθράκωσις).

REFERENCES

- DUKE-ELDER, S. (1965). "System of Ophthalmology", vol. 8, pt 1, pp. 1-598, pt 2, pp. 601-1242. Kimpton, London.
- IOAKEIMOGLU, G. (1939). "Pharmakology" (in Greek), vol. 1, pp. 11, 13.
- MATHAIPOULOU, G. (1923). "Organic Chemistry" (in Greek).