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THE CONTROL OF OPERATING-SUITE TEMPERATURES*

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Three main requirements influence the control of the temperatures of operating suites: (1) avoid humidities which contribute to the risks of anaesthetic explosions; (2) promote the comfort and working efficiency of the staff; and (3) conserve the patient's resources.

In the United States, an air temperature of 70 to 75°F. (21 to 24°C.) with 50 to 60% relative humidity provides a compromise between the requirements of the patients and those of the operators. In Britain, a temperature of 65 to 70°F. (18 to 21°C.) and a relative humidity of 50% is "well tolerated for many hours". In the U.S.S.R., air-conditioning should provide in summer an air temperature of 68 to 72·5°F. (20 to 22°C.) and in winter 66 to 68°F. (19 to 20°C.) with a relative humidity of 55%.

According to the American Society of Heating, Refrigeration and Air-conditioning Engineers (1961) Guide "little is known about optimum air conditions for maintaining normal body temperatures during anaesthesia and the immediate post-operative period". Clarke and his colleagues' observation in New York City that the patient's temperature begins to rise when the wet-bulb temperature exceeds 75°F. (23·8°C.) fills one important gap. But this finding may not apply to other populations. Deaths from heat stress have occurred in Britain with wet-bulb temperatures of this order; and in the tropics surgeons operate successfully without air-conditioning where the ambient wet-bulb temperature rarely falls much below 75°F. (23·8°C.). When temperature control is available, it is not only at high temperatures that trouble arises. Excessive cooling of the patient leads to cardiac arrhythmias.

The patient's position is more hazardous than that of those exposed to climatic extremes in industry or in the armed forces. He is not only unconscious but his responses may be poikilothermic in character because shivering is abolished and there is peripheral vasodilatation. When he is exposed to levels of warmth at which he might not maintain thermal equilibrium, his body temperature should be recorded continuously during the period of anaesthesia in the theatre and in the ward.

Earlier this year the National Health Service (1962) announced a major hospital building programme. There have been several papers concerning the principles of operating theatre design, and the Royal College of Surgeons of England (C. Wells, personal communication, 1962) and the Medical Research Council (1962) have appointed committees to examine these principles. It is questionable whether the thermal environment is yet receiving the attention it deserves, and this is not a new situation. About 10 years ago, correspondence in the *British Medical Journal* on the most suitable design for a surgeon's cap to prevent the sweat from dripping off his brow and onto the patient stimulated an enquiry at the Royal College of Surgeons of England as to whether sufficient thought had been given to the effects of sweat-provoking atmospheres on the efficiency of surgical teams (Ellis, 1953a). More recently, the tragic death of a policeman from heat effects following appendicectomy laid further emphasis on the need for studies to determine more precisely the thermal requirements of the patient as well (Lancet, 1961a, 1961b; Ellis, 1961a, 1961b, 1962; Wells, 1961).

In the order of importance which has been accorded to them in the past, the requirements which have influenced the control of the temperatures of operating suites are the need to avoid low relative

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humidities which contribute to the risks of anaesthetic explosions, the need to promote the comfort and the working efficiency of the surgeon and his staff, and the need to conserve the patient's resources so that he can withstand the operative procedure which he must undergo.

With regard to the first, there is general agreement that, provided the relative humidity is maintained at not less than 50%, there should be no explosion risk, and 55% is suggested as a reasonable aim (National Fire Protection Association, 1962). With regard to the second and third considerations, in the United States an air temperature of 70 to 75°F. (21 to 24°C.) with 50 to 60% relative humidity provides a compromise between the requirements of the patient and the requirements of the surgical team (A.S.H.R.A.E. Guide, 1961). In Britain a temperature of 65 to 70°F. (18 to 21°C.) and a relative humidity of 50% is said to be well tolerated by surgeons and patients for many hours (Douglas, 1962). In Russia, it is suggested that in summer operating-suite air-conditioning should provide an air temperature of 68 to 72·5°F. (20 to 22°C.) and in winter 66 to 68°F. (19 to 20°C.), with a relative humidity of 55% (Karpis, Simonovitch, and Sosin, 1961). When allowances are made for differences in climate, there is thus a good measure of agreement concerning requirements in the northern hemisphere, but the evidence to support these generalizations is poorly documented.

With modern equipment and techniques the anaesthetic explosion risk in Britain nowadays is usually minimal (H. K. Ashworth, personal communication, 1962). The factors which influence the comfort of the surgical team have received more attention than those which influence its efficiency or those which affect the patient. Even so there would seem to have been only one convincing study to determine the comfort zone for an operating theatre. This was made by Houghten and Cook (1939) at Pittsburgh during 123 operations, including 88 in an air-conditioned operating room. With relative humidities maintained at approximately 50%, these observers found that surgeons and interns enjoyed optimum comfort when the effective temperature was about 68°F. (20°C.), and the corresponding figure for the nurses was 69°F. (20·6°C.). Sensible perspiration appeared on the forehead of the surgeons when the effective temperature exceeded 69°F. (20·6°C.), which corresponds to an air temperature of 73°F. (22·75°C.) with a relative humidity of 58% and the low air speeds which are usual in operating theatres. These observations provide support for the standards to which the American air-conditioning industry works today. But some of the theatre staff were comfortable when the effective temperature was as low as 63°F. (17·2°C.) and others when it was as high as 74°F. (23·7°C.); and these observations were made during the summer months.

The variability in the thermal comfort requirements in different parts of the world, in different parts of any particular country, with changes in season, or with different levels of activity, cannot be ignored. For example, the scatter of the effective temperature zones within which people were thermally comfortable ranged from 57 to 63°F. (13·8 to 17·2°C.) in one study for workers employed in light industry in Britain during the winter (Bedford, 1936) to 73 to 78°F. (22·75 to 25·5°C.) in another study on men and women engaged in light activities in Singapore where there is little seasonal variation (Ellis, 1953b). In terms of the dry-bulb temperature, most industrial workers in Britain were comfortable between 64 and 66°F. (17·8 to 18·85°C.) (Bedford, 1936), whereas the percentage of acclimatized naval personnel on a tropical station who reported that they were "comfortable" (neither "too warm" nor "too cool") only began to fall off when the air temperature exceeded 83°F. (28·7°C.) (Ellis, 1952). These examples give some indication of the way the thermal comfort requirements of surgical teams might vary in different parts of the world. At the upper end of the temperature scale opinions on thermal comfort provide as useful a guide to the environmental needs of those who are not engaged in heavy physical exertion as any other yardstick available. Furthermore, for the type of work the surgeon and his team have to perform, which does not usually involve sustained heavy energy expenditure, the zone within which they are thermally comfortable is probably the zone within which they will work most efficiently.

The effect of the thermal environment on the efficiency of surgical teams has not been determined. Even the simplest techniques for measuring the effects of varying levels of warmth on efficiency in the laboratory have their shortcomings, and it is doubtful if satisfactory techniques are yet available for tackling the more difficult environmental situation encountered in the operating theatre.

The patient, even if he is conscious or semiconscious, which he frequently is not, is in the weakest position to declare his needs. His thermal environment may not always receive the consideration it merits from those whose attention is focussed primarily on other considerations. The level of warmth at which he is in thermal equilibrium will vary from person to person, with the clothing worn, with the coverings placed over him, and with a number of other factors. Any generalization should be interpreted with caution. The observation by Clark, Orkin, and Rovenstine (1954) for New York City, that when the wet-bulb temperature of the air exceeded 75°F. (23·8°C.) the body temperature of the patient began to rise, provided a notable contribution; but deaths from heat stress during or after surgical procedures have occurred in Britain with wet-bulb temperatures of this order in the theatre (Harris and Hutton, 1956), and what applies in New York may not apply in London or in Singapore. Further, surgeons have operated with success in the tropics for many years without air-conditioning in areas where the ambient wet-bulb temperature rarely falls below 75°F. Thus, just as the comfort zone varies around the world, so may the zone of warmth within which patients maintain thermal equilibrium, although this requires confirmation. The latest edition of the Guide and Data Book of the American Society of Heating, Refrigeration and Air-conditioning Engineers (1961) still states, as it has for many years past, that "little is known about optimum air-conditions for maintaining normal body temperatures during anaesthesia and the immediate post-operative period".

When adequate measures for controlling environmental warmth are provided, it is not only at high temperatures that trouble may arise. In a letter following a discussion on cardiac arrhythmias in Miami last year, Dr. Richard Lyons (personal communication, 1962) recalled how the surgeons at his hospital "would bring a patient into an air-conditioned room and proceed to eviscerate him whilst they were tailoring a new aorta and its attendant vascular connections only to find that the patient got in trouble with various arrhythmias which at first they could not explain until they recorded the patient's temperature, which at times, much to their surprise, was lowered into the lower 80°F. levels". He commented, "they have now become interested in maintaining the patient's temperature at a reasonably normal level whilst they make their plumbing connections".

If refrigeration and air-conditioning are available, there is a good chance of over-cooling the patient if one is not careful; and, if not, there is a good chance of over-heating him if the weather suddenly turns warm and one does not take reasonable precautions. This is a situation which is potentially more hazardous than many encountered in hot industries or in military operations which have been studied intensively. In the first place, the patient is usually unconscious. In the second, he may be a poikilotherm as well. Stephen (1961) and his colleagues (Stephen, Dent, Hall, Knox, and North, 1960) have pointed out that the responses of paediatric patients under general anaesthesia in particular are poikilothermic in character, because shivering is abolished and there is peripheral vasodilatation, and more so than in the adult because of the infant's large surface area in comparison to its body bulk. When patients are exposed on the hot or cold side of the environmental temperature at which they can maintain equilibrium, the view of Stephen and his co-workers that their body temperatures should be recorded continuously until the period of anaesthesia is terminated has much to commend it.

Measurements other than those of body temperature might also be helpful. In *Hot Climates, Man and His Heart*, Burch and De Pasquale (1962) comment on the markedly beneficial effects which they observed when treating patients with congestive cardiac failure, hypertension, and cerebrovascular disorders in an air-conditioned ward in New Orleans during the hot summer months of 1957 and 1958. The mean cardiac output of patients with congestive cardiac failure, who were exposed to excessively warm conditions, increased only about two times, as opposed to a four-fold increase in controls without cardiac disease, although the ventricular pressures of the cardiacs were generally greater than those of the controls, that is to say a greater pressure was required to eject less blood. A hot and humid environment, as opposed to the environment of an air-conditioned ward, was associated with increases in cardiac output, stroke volume, the mechanical and physiological cardiac work-load, and the tension on the walls of the ventricle. Excessive warmth in the presence of an impaired cardiac reserve due to heart disease might therefore precipitate acute left ventricular failure. They did not report observations on anaesthetized patients, which would add a further complication to an already complex situation.

A notable achievement in the United States Navy has been the development of a system for measuring the thermal environment out of doors and for defining the levels of warmth at which recruit training in Marine Corps Training Establishments during the hot season should be modified or suspended. The incidence of acute heat illness was dramatically reduced (Minard, 1961). This provokes the question whether, when the means for controlling temperatures in the operating suite are not available, information is available on the levels of warmth at which a surgeon should consider abandoning his list, deal with only the more acute emergencies, off-set the effects of warmth by reducing clothing and covering to a minimum, sterilize equipment elsewhere than in the vicinity of the theatre, or prepare to cool the patient with ice packs, cool mattresses or other means, if this should become necessary. Are impervious mackintosh sheets really necessary to minimize the risk of infection? It has been suggested that they are not, and studies to substantiate this view will be published shortly (H. K. Ashworth, personal communication). If rubber sheets could be eliminated, this would certainly go some of the way to bridge the gap between the thermal requirements of the patient and those of the surgical team.

In summary, a plea is made for a more precise definition of the thermal environmental requirements of the unconscious patient. If his needs are known and are met, there will usually be little need to worry about the comfort or the efficiency of the surgical team. The patient cannot be asked whether he is "uncomfortably warm" or "uncomfortably cold", but his deep body temperature and his mean skin temperature can be recorded, and variations in the latter correlate closely with variations in thermal comfort in the conscious subject.

Even if the day should come when accurate environmental control is generally available in most operating suites in the civilized world, and that day is yet far off, information of this sort will still be needed in time of war, in other emergencies, and in those countries which cannot afford the necessary plant and upkeep. It is essential to a systematic appreciation of these problems. The most sinister situation is not necessarily in the tropics or in the desert, where people are acclimatized and accustomed to coping with environmental warmth, but, perhaps, in more temperate zones when an unusually severe heat wave hits an unsuspecting, unprepared, unacclimatized community, as it did in Australia four years ago (Danks, Webb, and Allen, 1962).

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