# *Special Considerations in Design of the Operating Area*

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THE OPERATING THEATER is steadily becoming more complex. We have not seen for years the formerly-common situation where the surgeon had the family doctor assisting or "pouring" the ether. Now, doctors, nurses and technicians are specialists, each with an assigned responsibility. The newer procedures, the "spare parts" surgery, require large, well-rehearsed teams and prolonged time schedules. Electronic equipment for detection, control and resuscitative measures has saved many lives during these critical periods.

## Size of Operating Rooms

Operating rooms must be considerably larger than was thought necessary a few years ago. Space must be found for extensive anesthetic equipment, blood transfusion apparatus, oscilloscopes and other electronic monitoring equipment, resuscitators, etc. More technical experts are joining the team. For general surgery the room size required has increased from 320 to 360, and now 400, square feet—or more. For some procedures, such as heart transplants, a size of 550 square feet, or better, 600 square feet, is considered desirable. Maximum size is not so essential if there is a side room with a glass partition and adequate intercommunication for some of the equipment, but the preference is for one full-sized room. Rooms for cystoscopy and endoscopy generally can be a little smaller than the standard 400 square feet, depending upon the arrangement provided for the sterilization and storage of special instruments in an adjoining workroom. So-called "minor" rooms should be minor in equipment only and not in size, to permit greater flexibility in use in future years. For orthopedic work one diameter should be at least 22 feet, and preferably 24 feet.

Too many operating rooms still do not permit adequate space for nurse circulation between the team at the table and the equipment parked about the periphery. This is often because the operating suite is still in a single-corridor unit, which makes adequate sizing and good circulation difficult. A double- or multiple-corridor floor gives the building width which will permit operating rooms to have the size and, in particular, the relationships necessary for the best work. (The wider building is also better for delivery, radiology, emergency, physical therapy, dietary and other departments.)

Because space about the table is essential to good technique, this is one place where the planner is justified in insisting upon adequate space even though operating room square footage is one of the costliest spaces in the hospital to provide. Space for ancillary rooms for supplies, clean-up, equipment, staff, administrative areas, patient holding, conferences and teaching is badly needed in many hospitals. This emphasizes the danger of fitting the suite into an already circumscribed area rather than calculating the need and making that portion of the building conform. To facilitate future expansion, the suite should be located on a lower floor.

## Floors

The criteria for the selection of floor materials and finishes are clear-cut, for the basic needs are obvious: to be easily cleanable, non-absorbent, non-harboring of bacteria; to have the right degree of conductivity; to be durable under equipment traffic, resistant to the action of floor-cleaning solutions; to have long life; not to be conducive to slipperiness. U. S. Public Health Service requirements state that "in all areas where floors are subject to wetting, they shall have a non-slip finish."

One factor considered vital for many years but now being reconsidered is conductivity. With the increasing use of nonexplosive anesthetics, how long will it be necessary for hospitals to go to the considerable expense of installing conductive flooring and other con-

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ductive items?* Some hospitals have already discontinued the use of explosive anesthetics, and a number are designing a portion, if not all, of the operating theaters with nonconductive floor coverings.

Terrazzo has long been a favorite flooring for operating suites, but, as usually made, it cracks readily as the floor settles, and tends to break down in time from the movement of the heavy table or the effect of cleaning fluids; the addition of carbon to make it conductive has not seemed to add to its durability. As terrazzo ages and surface chips loosen, minute cracks appear which, to bacteria, must seem like the Grand Canyon.

Bacterial floor counts must be kept as low as possible. Litsky recommends that the count should not exceed 0–5 colonies of nonpathogenic bacteria per Rodac plate before surgery but may rise to 12 colonies during surgery.[1]

To do its part in controlling bacterial spread, the floor must be as free from cracks or hard-to-clean depressions as possible. Ceramic and other hard tiles are quite durable and can be made adequately conductive, but they are bounded by cement depressions which can harbor bacteria. Wet vacuuming is infinitely more satisfactory than the swishing around of a mobile incubator in the form of a bacteria-laden damp mop normally kept in a warm cleaner's closet, but some fluid is usually left in the crevices. The development of vinyl plastics gave us a hard-surfaced durable product which can be conductive if desired and which, in 9- or 12-inch tiles, has a finer and proportionately smaller aggregate of seams or joints. Sheet vinyl is still safer.

A completely seamless and impervious floor with a hard surface would be ideal. A product meeting most objections is a new conductive terrazzo made with a plastic matrix.† It is much more resilient than the old-style terrazzo, has a harder surface, and the bonding between the epoxy matrix and the aggregates seems to be more permanent under continued usage. The many potentially-dangerous joints and cracks are virtually eliminated, and the product is less absorbent than the former type of terrazzo. The floor can be trowelled in and made as a monolithic unit without divider strips.

* Dangers of grounding are considered later.

† Dex-O-Tex, made by the Crossfield Products Corp., 333 North Michigan Avenue, Chicago, Illinois.

## Walls and Ceilings

Wall and ceiling surfaces must be readily cleanable and be of a texture not conducive to the retention of bacteria. The U. S. Public Health Service General Standards of Construction states that "wall bases in any areas used for surgical and obstetrical procedures shall be integral with either the wall or the floor surface material and shall be without voids that can harbor harmful bacteria." Walls must be washable and "ceilings shall be washable in operating suites (and) delivery suites. . . ."

Traditionally, the walls of operating rooms were white or pastel glossy tile. This extended to the ceiling or, in some instances, to a height of six or seven feet with a washable paint-on-plaster or paint-on-cement finish above. This type of tiled wall is still popular, and with justification. A less expensive alternative is a glossy enamel finish, or a good washable paint. Washable vinyl plastic papers can be renewed when desired and have a reasonable life.

A recent alternative which is becoming widely recommended is an epoxy resin which can be sprayed on to form a continuous, seamless, impervious coating which can be washed as required. It has the great advantage of having no seams or cracks which could harbor bacteria. A promising product now available is epoxy mixed with fiber glass, which can be sprayed on to give an excellent surface.‡

### Planning the Ceiling

With floor space crowded and wall space at a premium, many of us have felt that the ceiling at least still had some open space. It is becoming obvious that this is not so, for the ceiling has become very "busy." Lighting can take up considerable ceiling space, particularly if general illumination is provided from a rectangular recess peripheral to the operating

‡ Plastic sprays to make an impervious coating on walls include Armobond, made by Deerfield Coatings Inc., South Deerfield, Mass.; Armite and Armtex, made by Desco Chemical Company, 717 Elk Street, Buffalo 10, New York; products of the Duron Company Ltd., 64 Industry Street, Toronto 15, Ontario.

light. More overhead space is preempted if the popular double-track lights are used. The increasing attention being given to large-volume air replacement in the operating room—laminar flow, mentioned below—may lead to large grids, or one huge grid, in the ceiling to permit air interchange with the minimum of eddies or back flows in the room. This, in turn, can affect the other ceiling installations.

A closed-circuit television camera above the table can add to the problem, especially if it is not set in the surgical light. The presence of an overhead circular viewing gallery can really cause problems. In the ophthalmic operating room, a ceiling column supporting an operation microscope may be needed.

### Overhead Outlets for Gases

Frequently there is space conflict between the movable operating lights and the overhead suspension for gases and suction. These have been developed to get the tubing, the so-called "spaghetti," from its annoying and dangerous location on the floor. Booms have been used to bridge the space between wall outlets and the tableside, but this arrangement has not been as satisfactory as the ceiling outlets for anesthetic gases, suction, oxygen, nitrogen and compressed air. Their most-mentioned disadvantage—that of limiting the repositioning of the operating table—has been largely overcome by installing two banks of outlets diagonally across and beyond the opposite corners of the table, thus permitting repositioning. This installation has the added advantage of making the alternative bank available to the surgeon, particularly for suction or for gas power for drills. The ceiling outlet has also been useful as a hook for intravenous equipment. This, too, can now be obtained on an oval or U-shaped track, a helpful arrangement but one which also requires more ceiling space.

In our experience one must guard against the tendency of builders to install the overhead outlets not where they have been carefully planned by the architect and consultant, but away over in the corner where they will not interfere with the lighting and other specified installations. Result: the same old "spaghetti" on the floor.

We can anticipate more ceiling outlets in connection with the increasing amount of electronic equipment used, as mentioned above. This may be relieved in part if in the future more use is made of telemetric or wireless electronic equipment.

There must be more careful planning of ceiling space. All immediate and anticipated installations should be assigned locations before final working drawings and specifications are completed. The heating and ventilating engineers, the electrical engineers and the architects must co-ordinate their plans during this stage. If necessary, certain equipment and arrangements being favored may need to be reconsidered.

## Use of Color

The use of color in the operating room has long been generally accepted. White walls are still popular and look medically clean, but walls of soft pastel colors or pearl grey are much easier on the eyes. The conventional drapes and gowns of green, or occasionally of grey, cause less constriction of the pupil than does white cotton under the intense light. Where there is color photography or color TV, green sheets or sleeves offer a pleasing contrast to the pink or red of the tissues.

## Lighting

The basic principles of lighting, too, have been settled. Many operations today last longer than in the past, and the avoidance of eye fatigue, or of blurred vision from nerve-strain flash scintillations, is imperative. Eyes must be rested, and a reasonable level of light throughout the room is a great help. Although large windows have long been "out," we still think we have lost something in not providing some alternative means whereby the ciliary muscles can rest at infinity for a few brief moments.

Inadequate room illumination can be dangerous. Tubing and wiring are still frequently found on the floor; these can trip people, or the connection can be broken when kicked, with potential tragic results to the patient. The greater use of monitoring and other equipment with dials and gauges also necessitates better general illumination. We believe that the general illumination should be higher than that which has often prevailed in the past. The old dictum of 50 foot-candles for general illumination is not adequate. We agree with Warwick Smith that 100 foot-candles is required, and we would add "at least" to that figure if we are to avoid undue ciliary contraction, and often pain to the eyes, on approaching the table.[2]

Accurate color reflection is of vital importance in surgery for the distinction of tissues and particularly for the detection of cyanosis, shock, or other abnormal coloring or appearance. Modern lighting has done much to improve color rendition, and some recent developments provide a white light rated as approaching perfection.* One new operating light with a variable lighting intensity of 2,000 to 5,000 foot-candles has a color "temperature" rating of 6,000° Kelvin—perfect color clarity being 6,500—which rating is much above that of other operating lights and, for practical purposes, gives a color valuation indistinguishable from daylight. In the fluorescent field a British light now being introduced into America † has a general Color Rendering Index (Ra) of 96 (International Commission on Illumination) with a color temperature of 4,200° Kelvin.

## Environmental Control

The whole subject of air control in the operative suite needs greater attention by all who design hospitals. It is not that there have not been informative and convincing studies; it is rather that these ideas have not got through to the individual planner or local building committee, or to the surgeons themselves.

It is now accepted that the operating suite must be "air conditioned." But that is still interpreted by some to mean mainly air cooling, with some mechanical filtering of the air by filters which may thereafter receive little attention or change. Air may, or may not, be exhausted near the floor. In central northern areas and in regions of excessive dryness there is an increasing attention to humidification. Control of bacterial contamination and its sources is still somewhat confused in the minds of many involved in the planning of the operative suite. With respect to installed bactericidal equipment, many of us are concerned over conflicting claims and would appreciate completely independent, scientific appraisals of relative efficiency.

That the air should be the right temperature (68 to 76 F), the desired relative humidity (45–55 RH, depending upon the outside temperature) and the required ventilation rate (minimum of 12 to 15 volumes per hour except for laminar flow) is generally accepted. There is some difference of opinion, however, respecting the reuse of air in operating rooms. The Hill–Burton Act does not permit the recirculation of air in operating rooms. The U. S. Public Health Service requires a ventilation rate of 12 outside air changes per hour. It is understandable that hospital surgeons have been basically averse to the recirculation of air, even from within the suite itself, because of the potential danger of cross-infection and the smell of the older anesthetics.

Engineers are quick to point out that, from the bacterial viewpoint,[3] present filtration processes can make recirculated air safe. The few bacteria remaining are a very minor threat to the patient compared with the contamination of the air by the surgical team's breathing and talking right over the incision and the breaking of technique by many individuals in the central sterilizing room, by the orderly and his far-wandering stretcher, or the floor contamination tracked in from the changing rooms. Moreover, the human body can usually handle and kill a few scattered bacteria.

Actually, with increasing contamination and pollution of the atmosphere, outside air *per se* is not the pure article it is supposed to be. While smog and pollution by chemicals or fallout may not necessarily affect surgical results, studies have shown hospital air contamination from nearby outside sources, guano and debris from pigeon nests in the intake ventilators, or too-close proximity of the intake and output ventilators on the hospital roof.[4] As for anesthetic smells, these have become negligible or absent as the choice of anesthetic has changed. However, we must still have some outside air (15–25 per cent) to ensure adequate oxygenation, dilution of gases and the avoidance of "staleness."

Increasing emphasis is being placed upon keeping down the particle content of the air.

* The Daystar light produced by the Castle Company, 1777 East Henrietta Road, Rochester, New York 14623.

† Made by the Philips Electrical Ltd., Lighting Division, Century House, Shaftesbury Avenue, London WC2, England.

In large centers the content of the outside air may rise to 250–300 million particles per cubic foot; good filters can reduce this to five million or fewer per cubic foot. This makes the discrimination between recirculated and outside air of little importance from the viewpoint of potential bacterial contamination.

### Laminar Air Flow

Laminar air flow can be a protective factor in minimizing contamination in the operating room and elsewhere.[5, 6] This is effected by a wide area inflow of filtered air through an appropriate large grid and its withdrawal by an equally efficient process on the opposite side of the room. Bacteria are swept away before they can settle. This flow, which should be rapid and steady (60–100 fpm and up to 500–600 changes per hour), may be vertically laminar from ceiling to floor, or horizontal from one wall to the opposite wall. Theoretically, there should be few, if any, eddies and little turbulence. A rapid flow is desired to lessen the turbulence and resultant increased deposit of bacteria-laden particles. Some positive pressure (0.1 in. WG) is necessary to prevent ingress of untreated air. Interesting pilot installations have been developed.

Some research workers prefer vertical to horizontal laminar flow, but, from a practical viewpoint, we doubt that vertical laminar flow is superior in the operating room. Anyone who has experimented with a little cigaret smoke realizes that the heat of the overhead lamp has a strong influence on any adjacent air currents. The use of a plastic curtain surrounding the tableside team and a floor lamp rather than a ceiling lamp does seem to reduce turbulence, but how many surgeons would care to do all their operations that way? Of more concern, the air comes right past the heads of the operating team towards the patient's body. Now that in many hospitals the air comes into the operating room practically bacteria free, the greatest remaining airborne menace to the patient is the bacterial fallout from the operating team itself, particularly if the surgeon is demonstrating to colleagues or students, or does not cover his nose. Face masks are only partially effective.

With horizontal laminar flow, the current should flow from the foot of the table to the head except in special circumstances. This minimizes the chance that droplets from the surgical team will enter the wound, or contaminate the instruments, and eliminates the possibility of contamination from the anesthesiologist except, of course, in head or neck surgery.[7]

## Elective Outpatient Surgery

This service is assuming greater importance as the costs of hospitalization rise and as the never-ending struggle to obtain adequate beds makes it increasingly desirable to give as much service as possible without admitting the patient. More and more hospitals are setting up surgical units for those less-exacting procedures which can be done, usually by appointment, on an outpatient ambulatory basis. With the shortage of competent office help, doctors now find that many former office procedures can be done more satisfactorily in the hospital's elective minor surgery unit. These procedures usually are done for paying patients, who go directly to the outpatient surgical suite, are prepared, operated on and returned home after a short period in a recovery or holding area.

The unit may be adjacent to the main operative suite or, more suitably, may be a separate unit contiguous to the emergency department. Some hospitals are designed so that all three suites, and radiology, can be on the same floor close together. This arrangement has much to recommend it from the viewpoint of staff availability, utilization of nursing personnel, accessibility of special equipment, and availability of space in case of disaster.

Essential features of the facility are:

1–3 minor operating rooms

1 or more procedure rooms, including endoscopy

Necessary doctors' dressing room, preparation room, scrub area, sub-sterilizing, utilities, toilets, supervisors' office, supply room, etc.

Recovery or holding area of a size commensurate with estimated usage. This area could be shared with the emergency department, if individual privacy can be arranged.

## Potential Dangers of Electrical Equipment

The subject of electrical hazards is being dealt with elsewhere in this symposium and will not be included here, except to mention one aspect of the subject which, in our opinion, is not adequately appreciated.

The increasing use of electronic equipment in the operating theater is causing medical electronics engineers much concern.[8] It is exceedingly difficult, except at considerable expense, to prevent a certain degree of leakage current within the case. If the case is not adequately grounded, the voltage can rise and, if the patient becomes part of a grounded circuit, as can readily happen, he becomes a conductor. Ordinarily this might not be serious, but it can be very serious—and fatal—if the normal resistance of the patient through the skin is lowered by having the current go through an internal pacemaker, or an electrolyte-filled cardiac catheter, or a wire-connected catheter-tipped transducer, or even intrabronchial or intraesophageal equipment. Apparently the danger then becomes increased a thousandfold.

It has been stated by Whalen and Starmer that "Patients have been accidentally fibrillated by improperly grounded densitometers, amplifiers, power injectors and x-ray machines. The relatively high resistance of a standard dacron cardiac catheter filled with physiological saline (approximately 300,000 ohms) which may limit delivery of dangerous currents to the heart is often negated by the use of low-resistance metal guide wires. Electrode catheters used for intracardiac E.C.G. and shunt detection must be used with extra caution because of their low resistance."[9]

Hopps points out that danger is present when there are multiple ground points in a room with a potential difference between them.[10] He notes that the countershock defibrillator is inherently dangerous and that, paradoxically, there is more danger to the operator than to the patient. The newer type of defibrillator employs a capacitor-discharge shock of several thousand volts and the output may or may not be isolated. If it is not, contact with the "hot" electrode during the shock application could be fatal. Accidents resulting from replacing a three-prong with a two-prong plug in heart catheterization, in operations for aortic aneurysm and in other situations, have been reported. It is believed that many deaths formerly attributed to the manipulation, to the anesthetic given, or possibly to the dye used, were really due to electrically-induced fibrillation.

To the clinical worker who is not an electronics engineer, the situation is confusing. Grounding can be a protection or a hazard. New and complex equipment is being sold by representatives who apparently have neither the knowledge of, nor respect for, the potential hazards presumably known to the engineers who developed the equipment. And hospital equipment is applied all too often by individuals with little or no knowledge of how to check for and forestall calamitous discharges. Carl Walter has stated "The unique requirements for safety involved in the care of the hospitalized patient are ignored by designers." He insists that "Each appliance must perform on its own—reliably and safely under adverse conditions—along with other appliances similarly neglected. Appliances must be fail-safe, tamper-proof, and maintenance-free."[11]

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