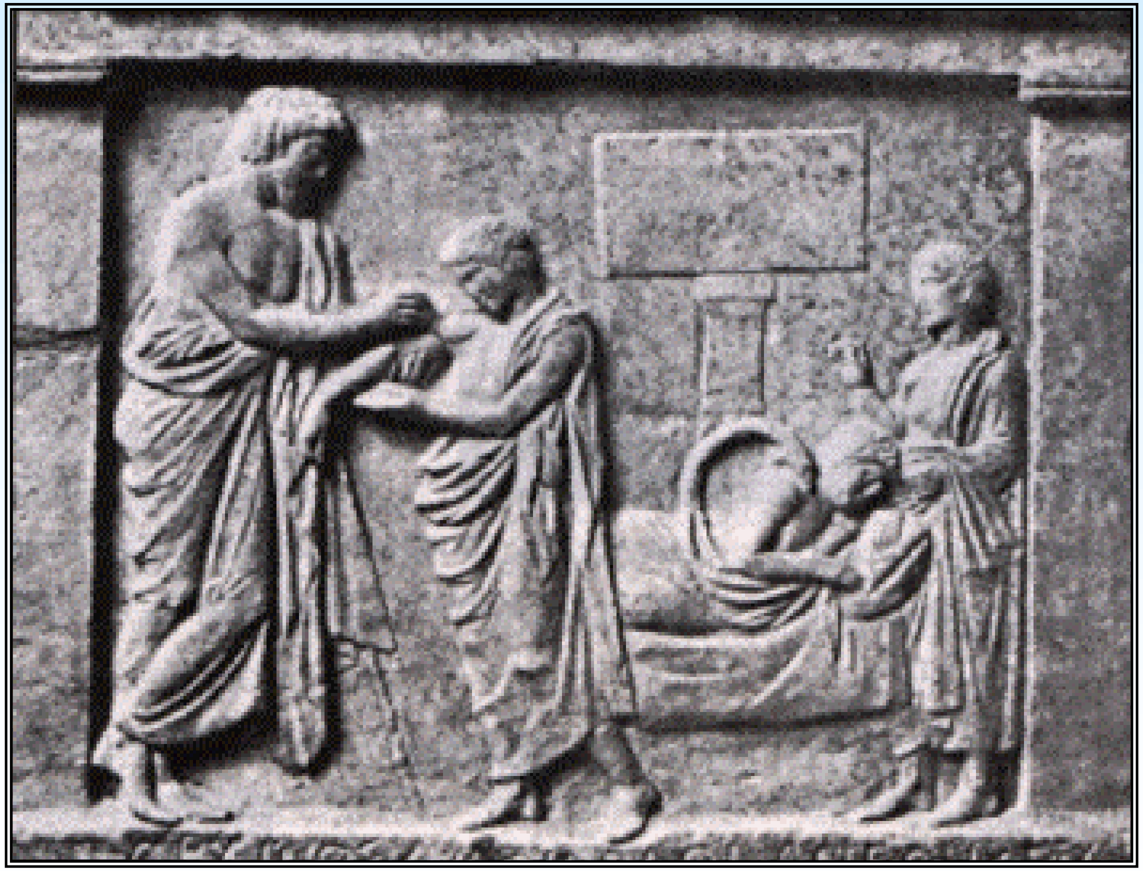
EQUIPPING THE ICU/CCU



Care provided in an Intensive-Care Unit

- The quality of care available in an intensive-care unit is related first and foremost to thw quality of the nursing care and to the clinical acumen of the medical staff. But without the necessary equipment and an appropriate environmental design, the safety, efficiency, and economy with which the patient care is delivered will be lessened.
- In determining what equipment should go into an ntensive-care unit, the entire functional program must be kept in mind, especially such programming factors as type of patients to be cared for, patient load, and size of the unit.

Most common ICU

- Most hospitals of more than 200 beds will have at least two separate ICUs:
  - *A medical-surgical ICU (MSICU)*
  - *A coronary care unit (CCU).*
- Larger hospitals usually separate the MISCU into a medical and a surgical unit and to provide specialty ICUs in a number of medical specialties, depending upon the requirements of patient load (*burn , neonatal* etc.).

Development and Implementation of an ICU

Development and Implementation of an ICU should include following steps:

- *Planning and organization.*
- *Training nursing and physician staff.*
- *Building and equipping unit.*
- *Opening unit.*
- *Developing standards and protocols.*
- *Training allied health professionals.*
- *Continuing education of physicians and nurses.*
- *Developing physician coverage.*
- *Developing research programs.*

A typical intensive care unit bed

A typical ICU bed-side monitor equipped with:

- *ECG.*
- *Arterial Pressure.*
- *Temperature.*
- *SvO2, and SpO2 modules.*

Equipping an ICU

- A good approach to equipping an ICU of any type or size is to define the functional systems.
- All equipment can be classified into the following systems:
  - *Environment.*
  - *Traffic and commerce.*
  - *Communication and information (records).*
  - *Administration (management).*

Environment

- Facilities: location, purposes to be served, type and load of patients, traffic.
- Design: areas configuration, cubicles, number of beds, special treatment rooms.
- Finishings: acoustics, color, texture, doors, windowed walls of cubicles.
- Electrical services: monitoring, ground, lighting, outlets, RF shielding, service rails, X-ray.
- Mechanical services: ventilation, heating, air conditioning, gases, vacuum, plumbing.
- Hazard control: infection, electrical, mechanical, maintenance, housekeeping.
- Visitors facilities.

Traffic and commerce

- Cartage for patients and supplies, storage of cartage, cart cleaning.
- Materials handling and storage.
- Equipment for delivery, storage, dispensing, and disposal of all materials.
- Information and data processing related to materials handling.
- Hazard control.

Communication and information (records)

- Telephone (intra- and interdepartmental).
- Intercome.
- Closed circuit television.
- Electronic monitoring (bedside; nurses’ desk; offices).
- Data processing.
- Computer network (paperless records).
- Manual record keeping.
- Hazard control.

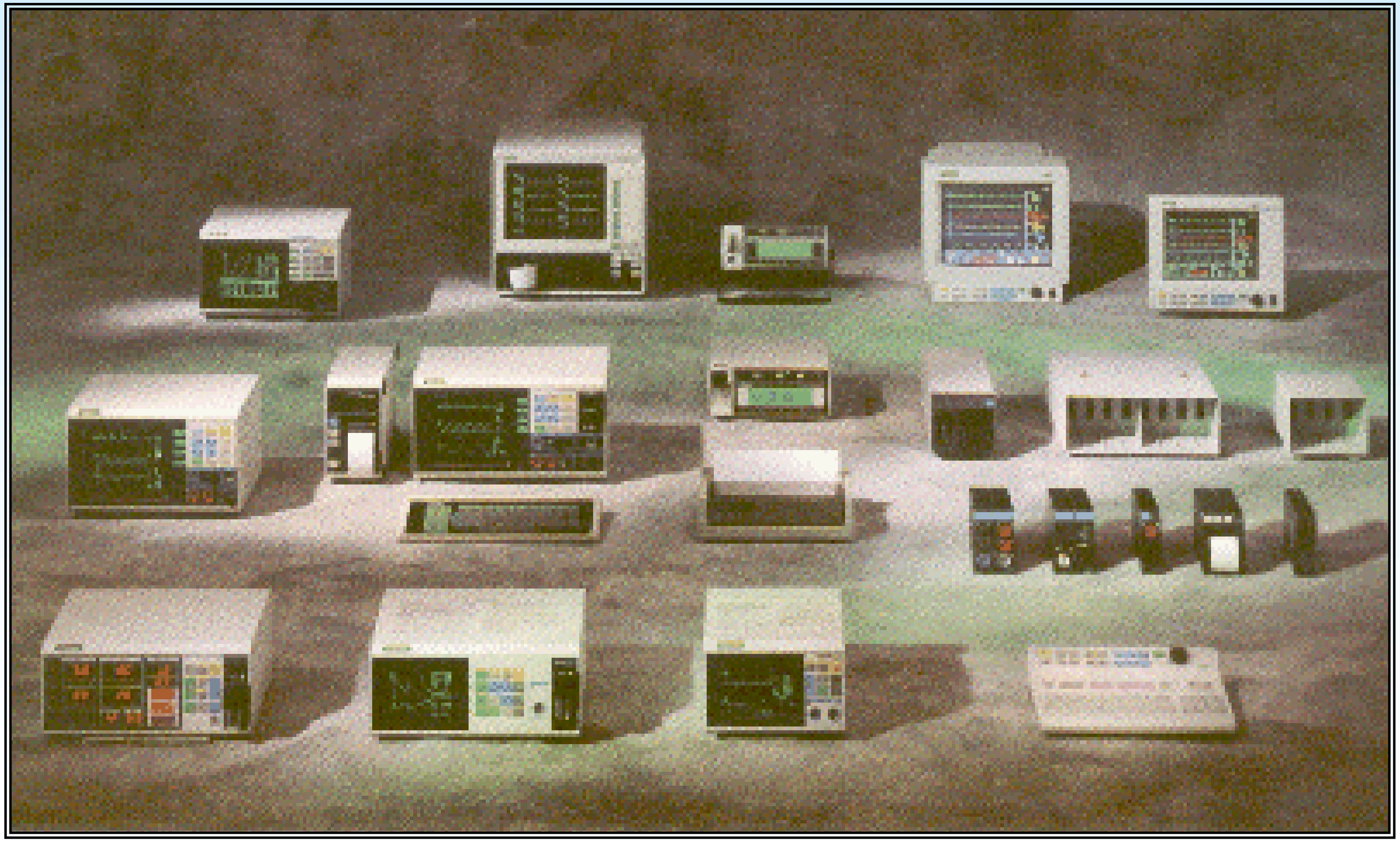
Administration (management)

- Office equipment.
- Procedure systems.
- Staff lockers, call rooms.
- Records system.
- Hazard control.

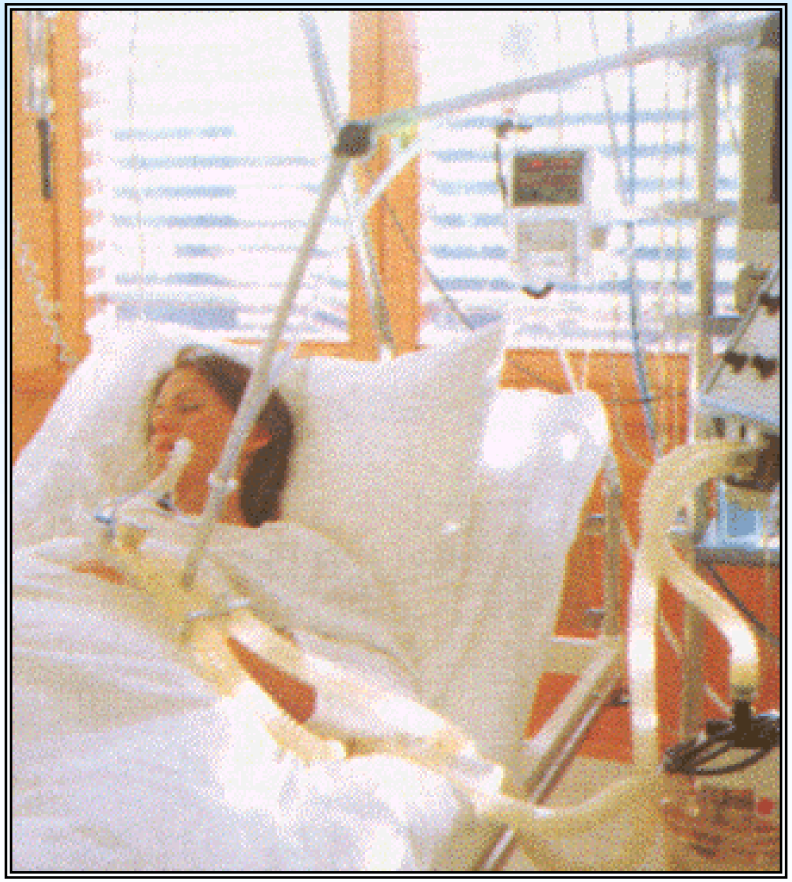
ICU classification

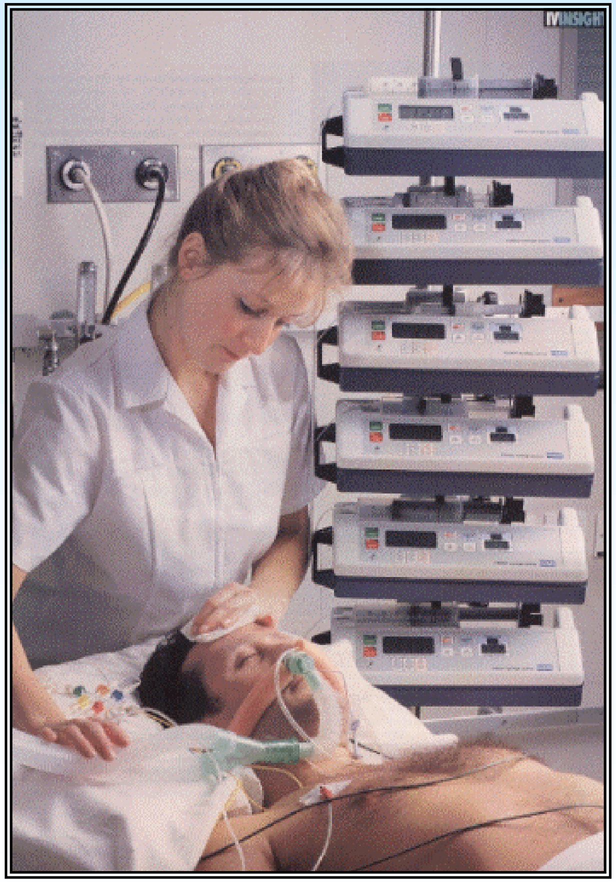
- An ICU can be classified according to:
  - *Medical specialty (surgical, medical, pediatric, neonatal, fetal-maternal, etc.).*
  - *Organ system (respiratory, cardiac, renal, neurological, hepatic, etc.).*
  - *Clinical syndrome (trauma, shock, burn, etc.).*
- An ICU can be also mobile (ambulance car, helicopter etc.).

Patient Monitors

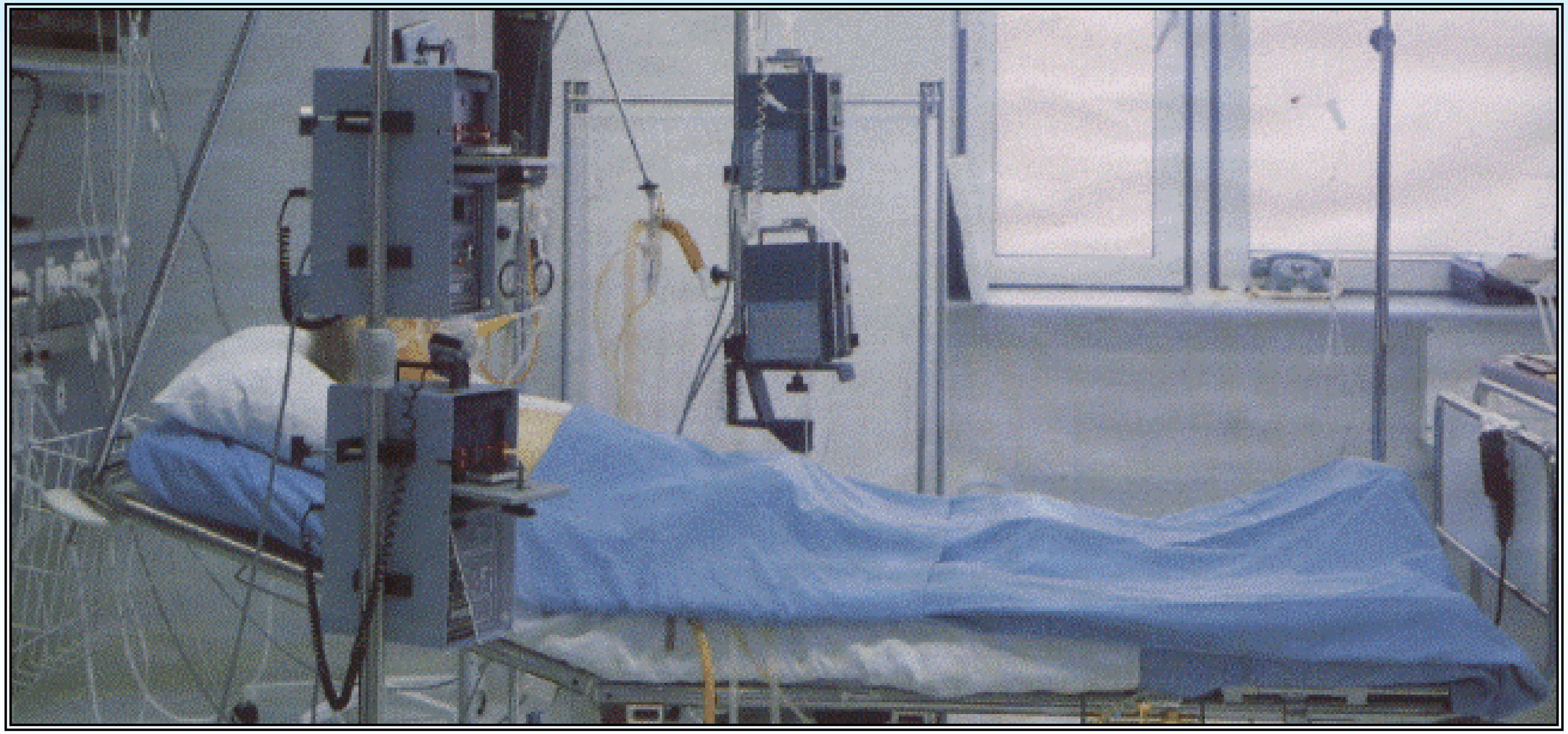


Long-term Ventilation





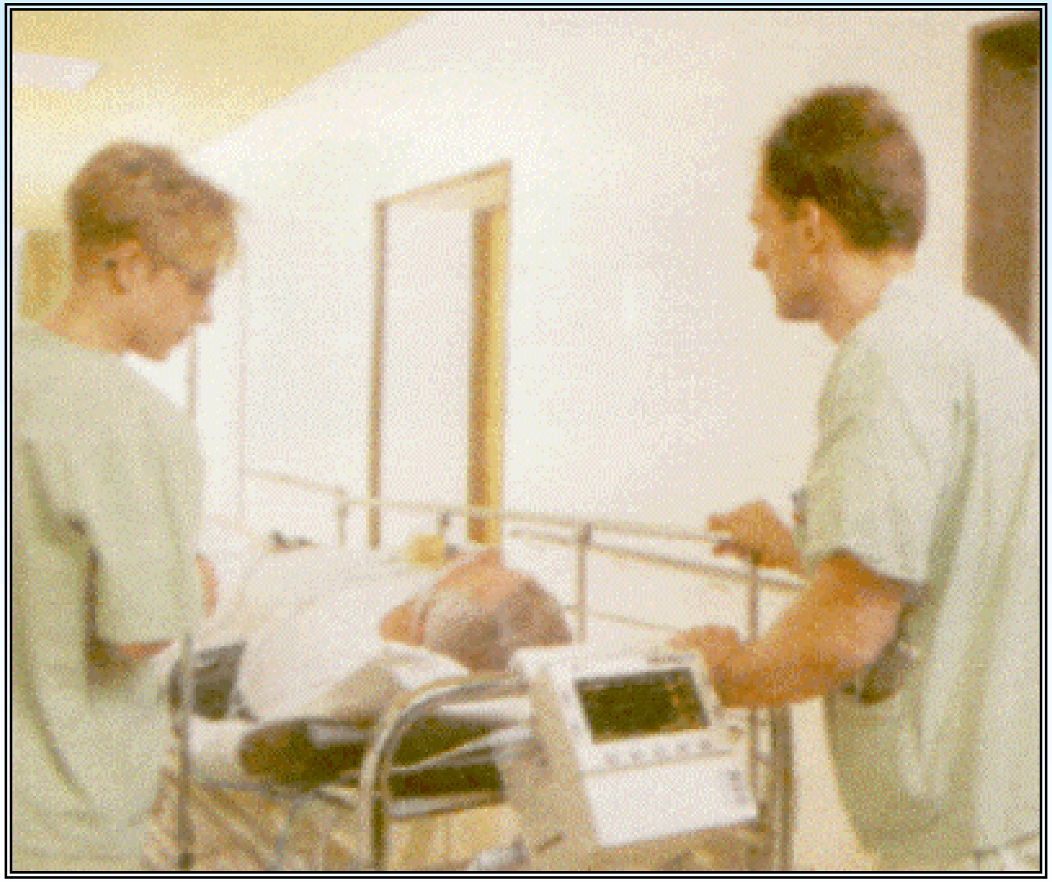
A typical intensive care bed arrangement



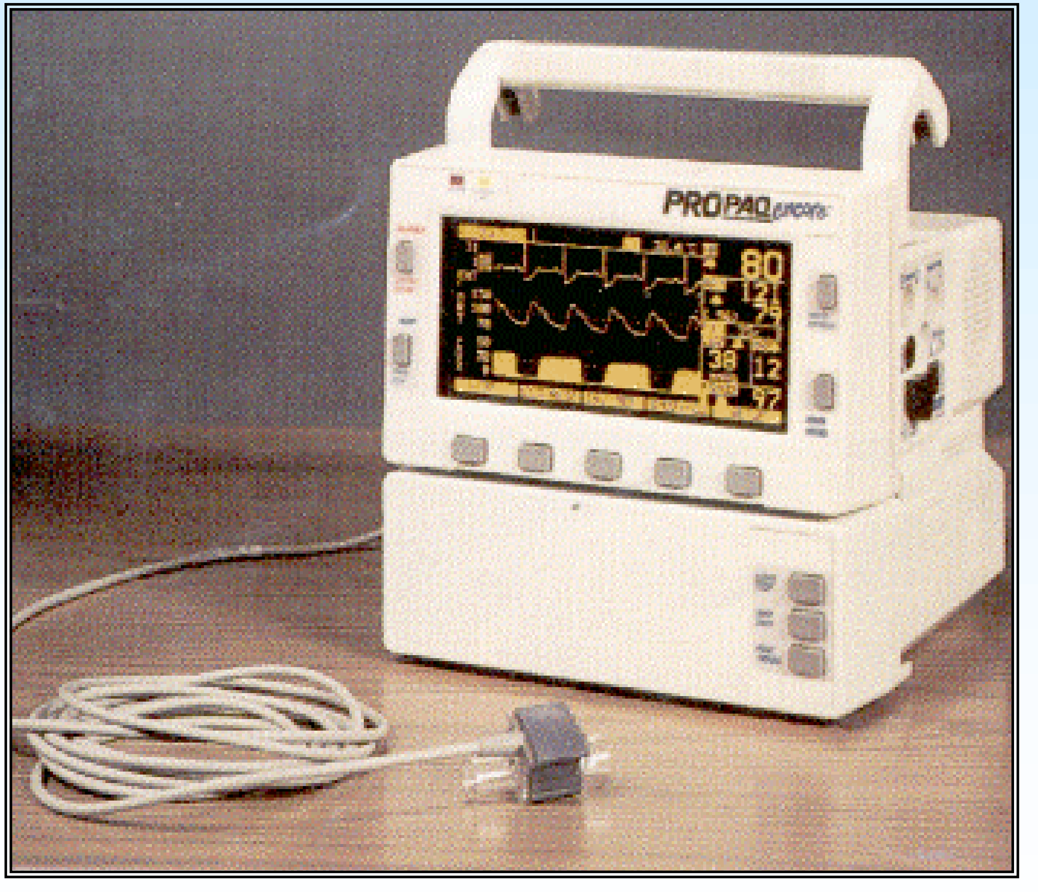
Service Rails

ICU and Recovery Room Stretchers

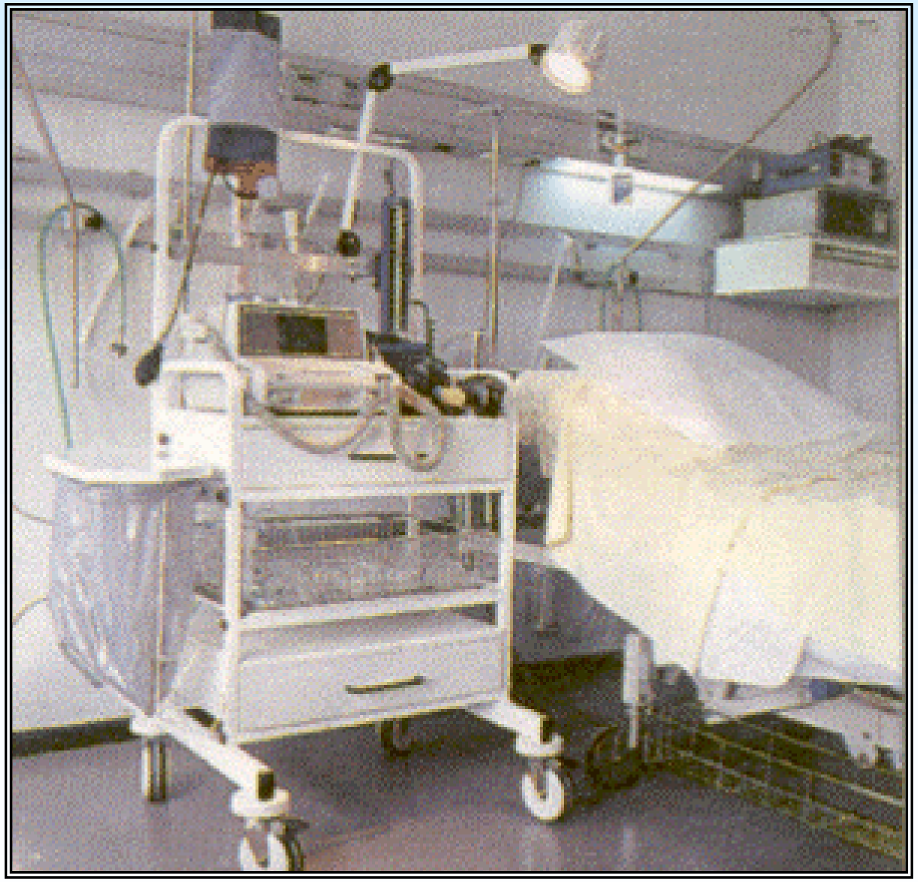
ICU-patient Transportation



Mobile monitor



ICU Illumination - Auxilliary Equipment



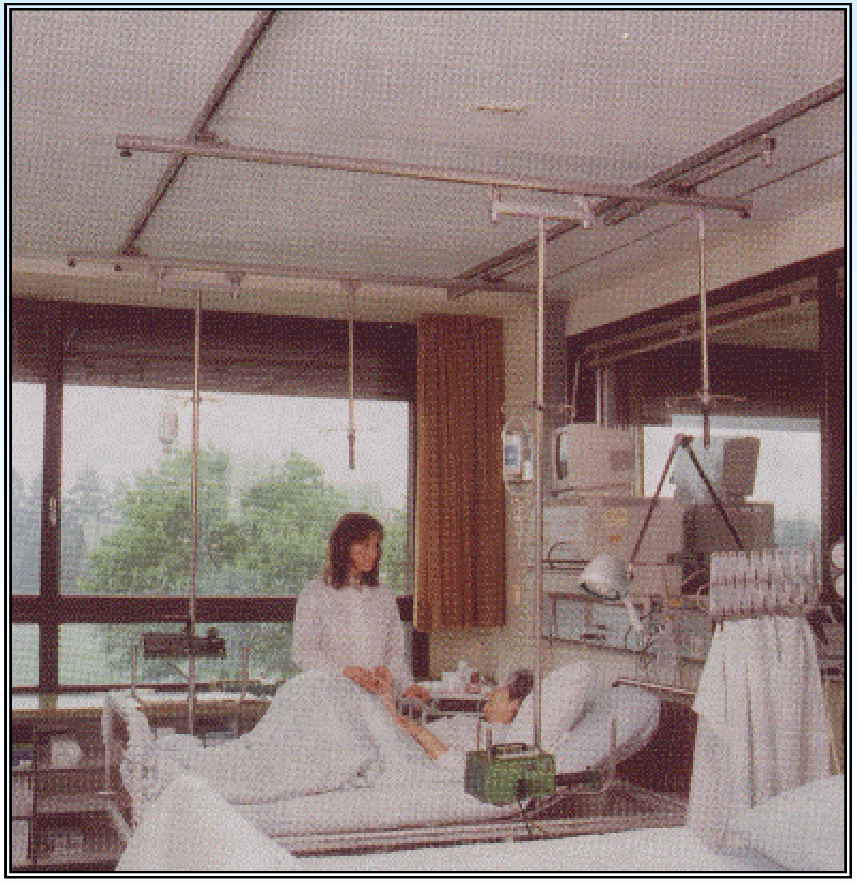
Environmental Safety

- Environmental safety is based mainly on mechanical engineering services, that provide a biologically safe environment. Following points should be taken into acount:
- The bed-head units should contain at least:
  - *Two oxygen, two vacuum, and one filtered compressed air outlets, properly signed and manufactured outlets.*
  - *Four double three-prong electrical outlets and the two ground jacks for equipment and an examination light.*
- The ambient temperature of the ICU should be about 27 - 31 ^{o}C.

Ventilation in the ICU

- Important for the ventilation in the ICU is:
  - *The rate of air exchange (6-25 times/hour).*
  - *The directionality of the airflow.*
  - *The cleanliness of the air (HEPA filters are required when air recirculation is performed).*
- Desinfection of the air includes *germidical aerosols*, *air handling*, and *UV light*.
- Optimal air humidity has been designated as 50-55% for both, patients and personnel.
- Serious attention is paid to the pressure of air in various portions of the ICU.

Ventilation of the ICU - Isolation

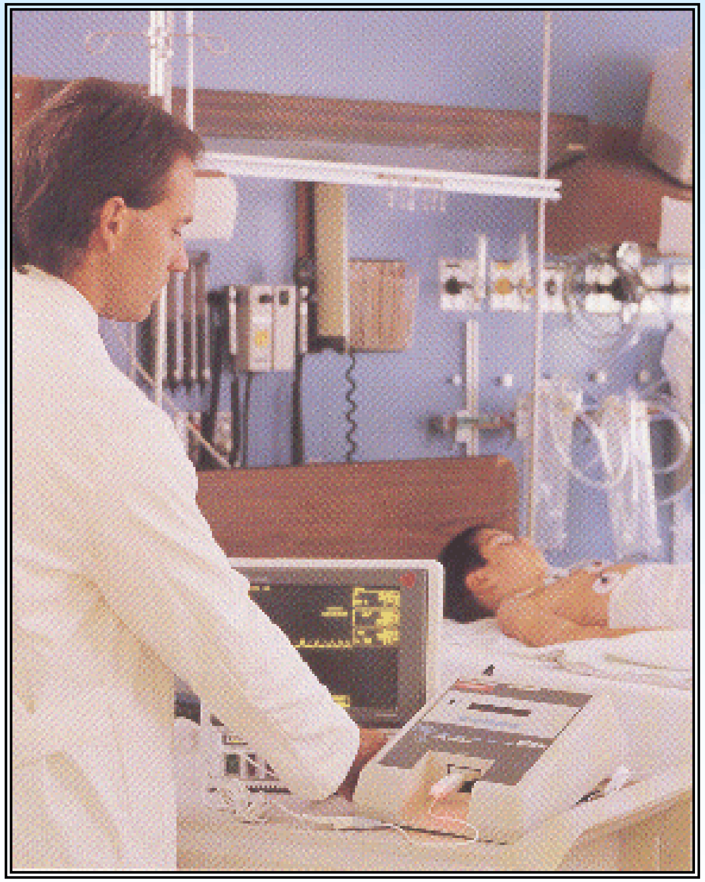


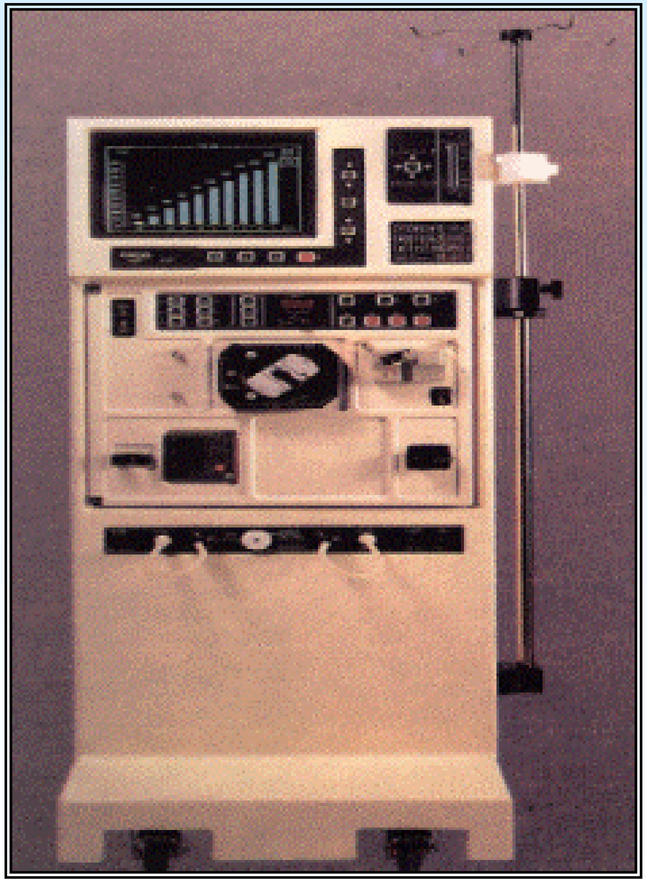
Maximal ICU support

In special cases, such as in a burn room a multiple organ support system may require:

- *A haemodialysis unit.*
- *A respirator.*
- *An arterial blood pressure catheter and transducer unit.*
- *A monitor for ECG and blood pressure.*
- *A heater.*
- *An IV drip regulator.*
- *A pulmonary artery and wedge pressure monitor.*
- *An intra-aortic balloon pump.*

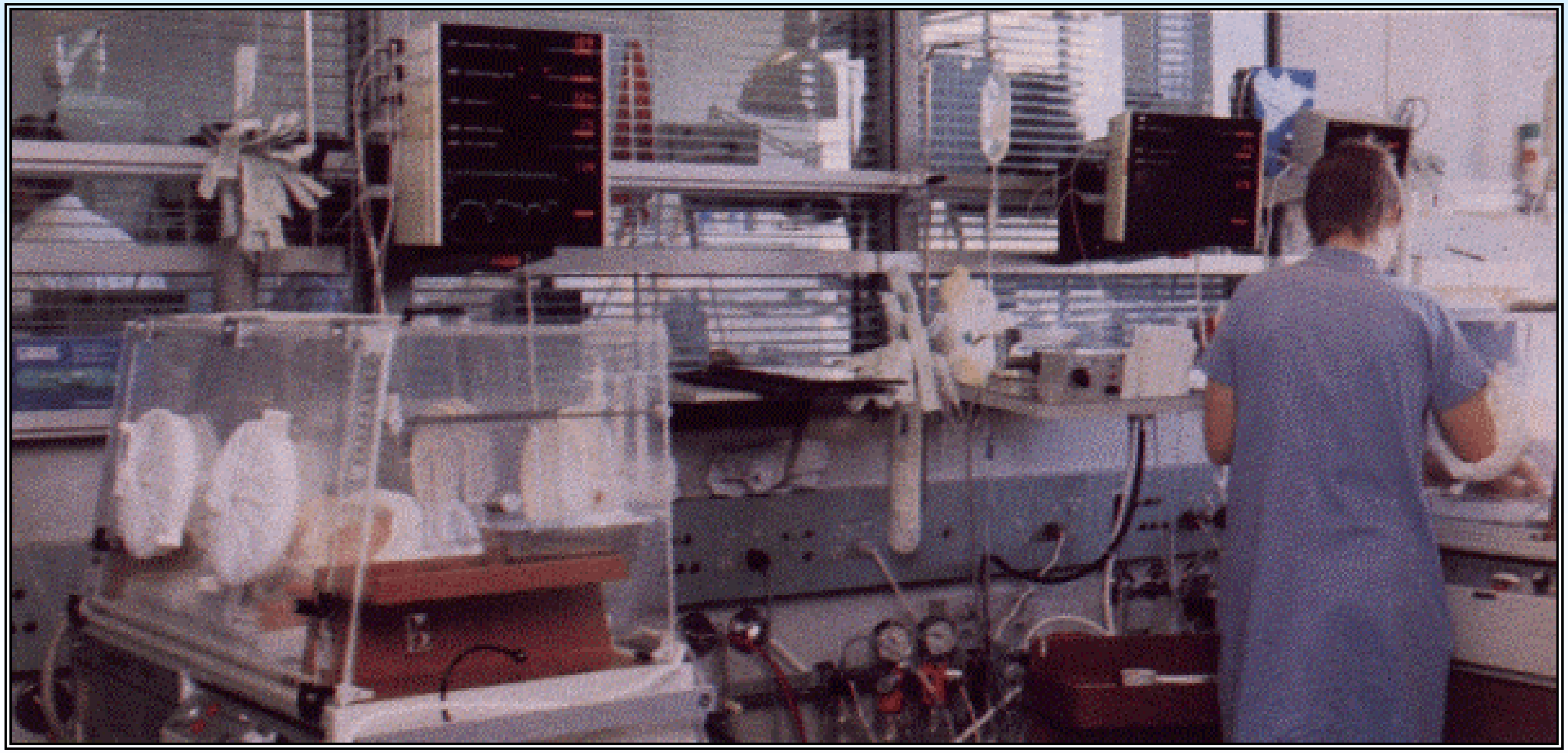
Haemodialysis Unit and on-site Laboratory Support in the ICU



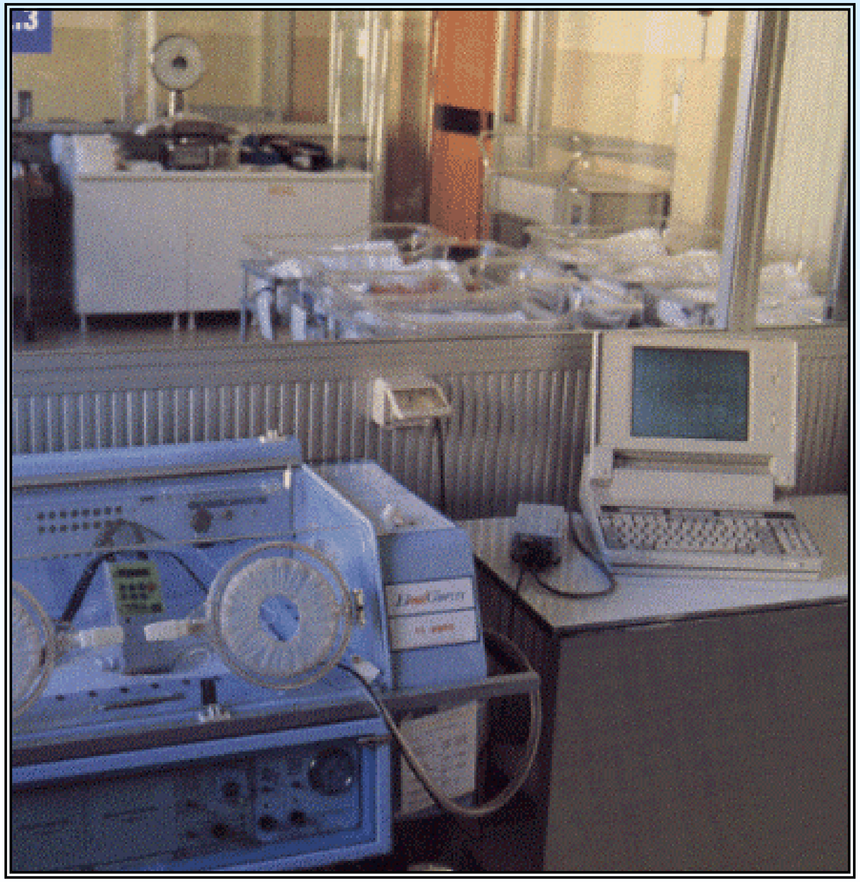


Radiological Support in the ICU

Neonatal ICU

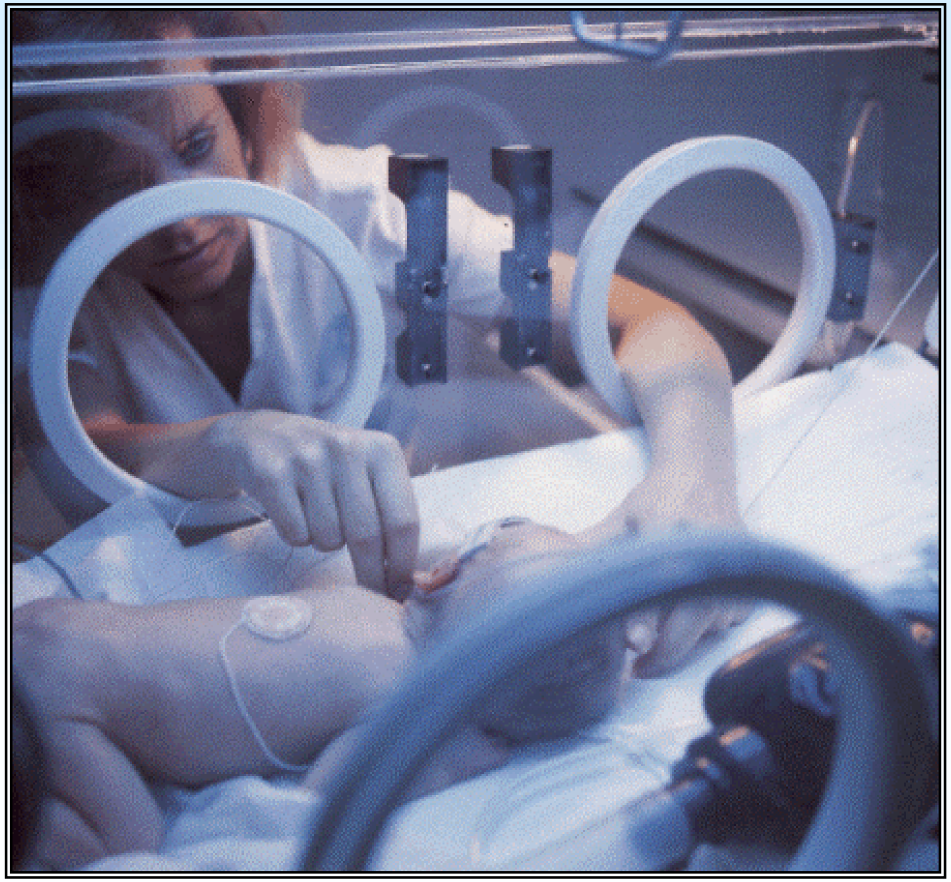


Newborn Room and Standby Incubator



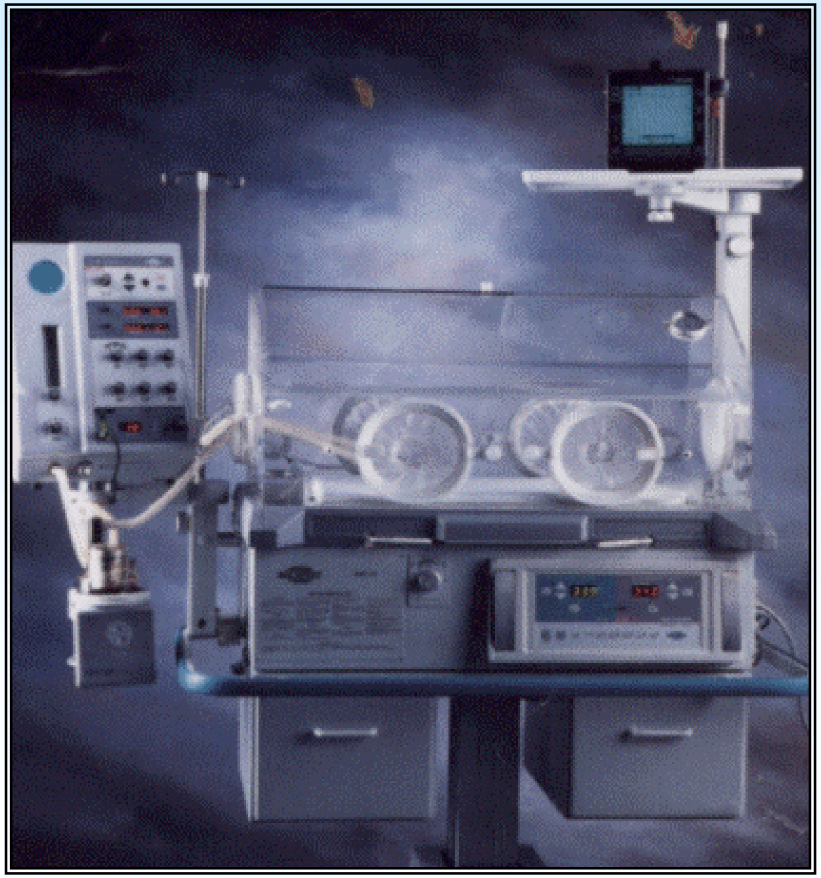
Improved Environmental Conditions for the Newborn in the Incubator

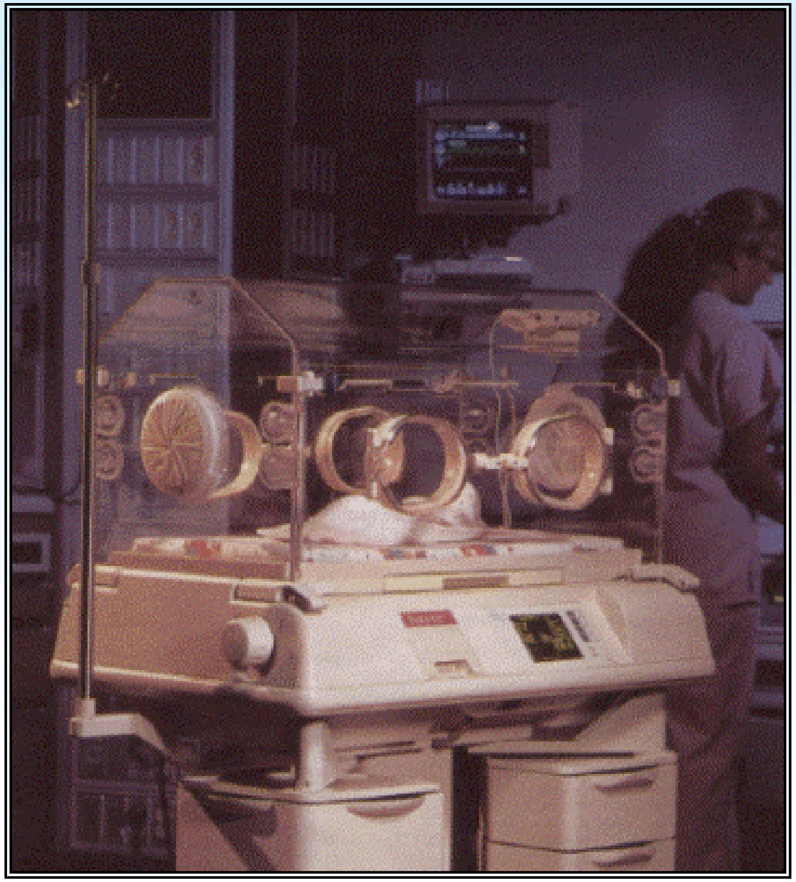
Newborn Skin TemperatureMeasuremnt



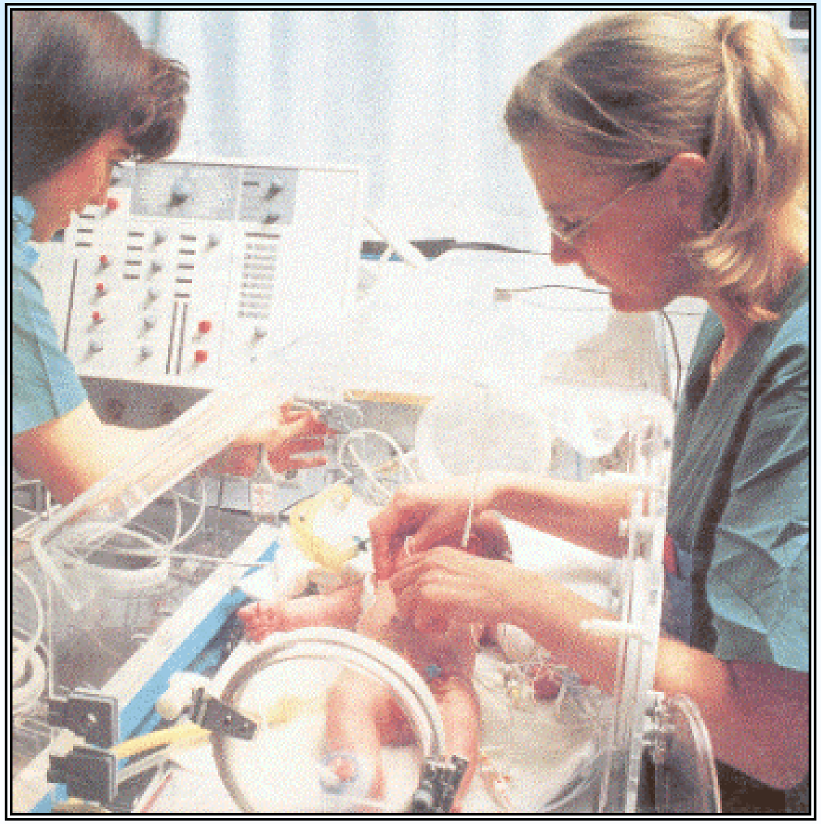
Newborn Biosignal Monitoring

Newborn Biosignal Monitoring and Vital Function Support

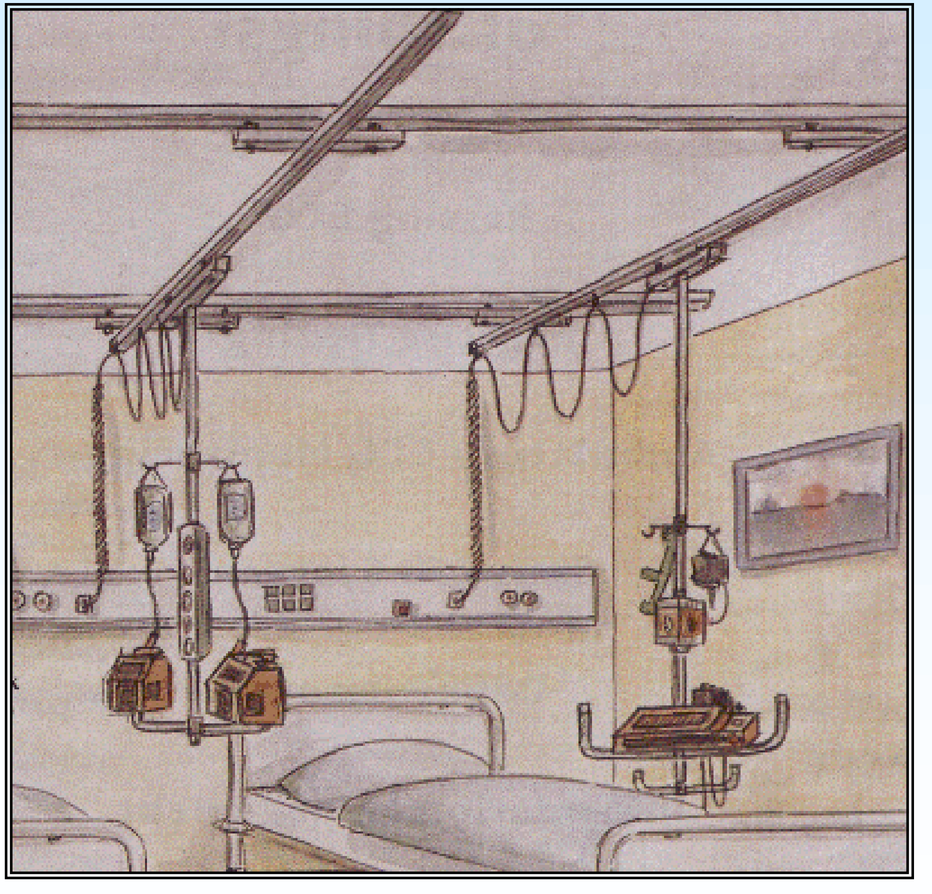




Newborn care in the Incubator



Electrical safety in an ICU



Electrical safety

- *Electrical safety* is the best possible limitation of hazardous electrical Macro - and/or Microshocks, sustained by patients, as well as, explosion, fire or damage to equipments and buildings.
- The scope of the following presentation is mainly the examination of the electrical safety of monitoring and resuscitation equipment in the ICU, CCU and Operation Department, according to IEC 601.1.

The IEC 601.1 Standard

- The IEC 601.1 Standard applies to the safety of Medical Electrical Equipment, provided with no more than one connection to a particular supply mains and intended to diagnose, treat, or monitor the patient under medical supervision and which makes physical or electrical contact with the patient and/or transfers energy to or from the patient and/or detects such energy transfer to or from the patient.
- Although this Standard is primarily concerned with safety, it contains some requirements regarding reliable operation where this is connected with safety.

Electrical Safety

Electrical safety in an ICU is a shared responsibility between several parties, in addition to the physician, including:

- *The nurses.*
- *The electrical engineers.*
- *The biomedical engineer.*
- *The clinical engineers.*
- *The manufacturers of electrical medical equipment.*
- *The hospital.*

Critical points concerning Electrical Safety

- The electrical installation *(including four double three-prong electrical outlets and the two ground jacks for equipment for every bed)*, no matter how safe, is only part of the safety requirements.
- Plugs and cords must be checked and rejected if defective.
- Only devices tested for safety should be used.
- Electrical compatibility of the entire electrical system must be tested regularly.
- Patient leads must be attached and connected properly.
- Radiofrequency devices (including mobile telephones) must be excluded.

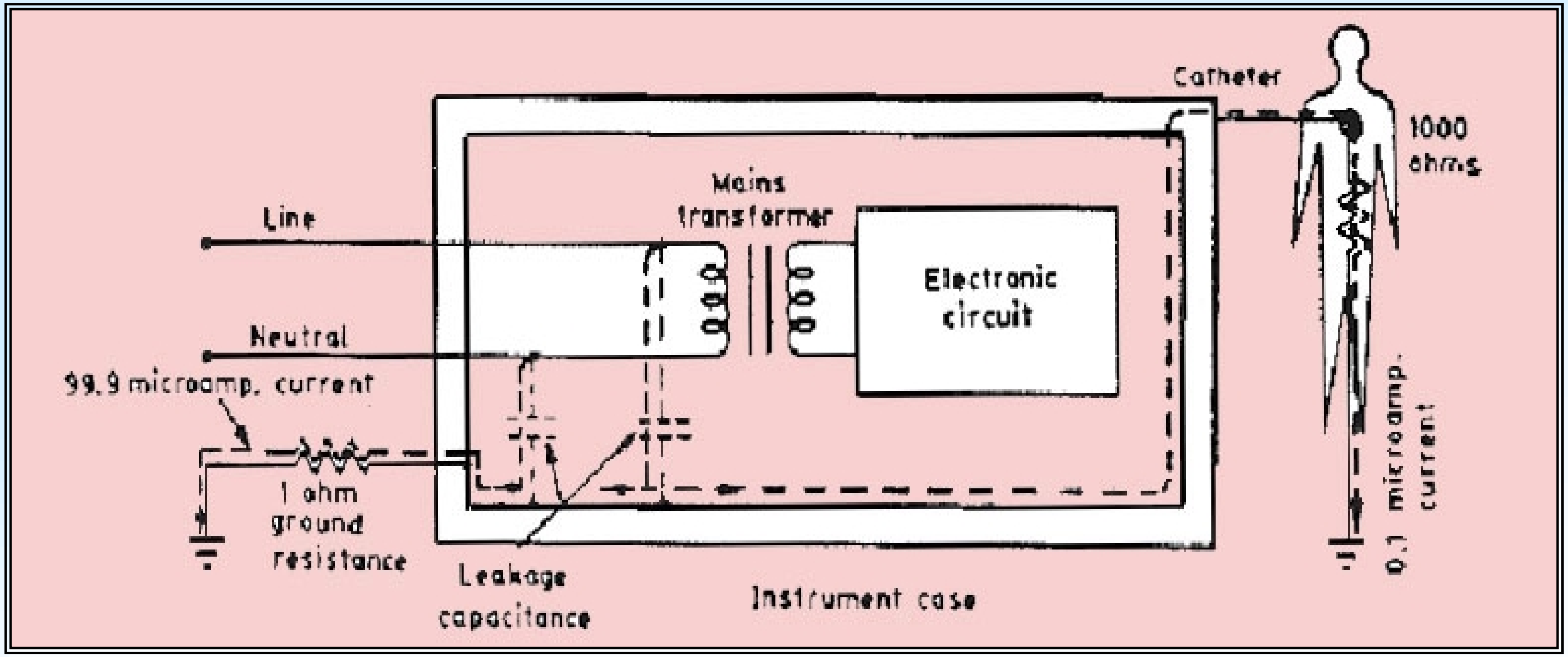
Microshock

- *Microshock* is a form of electrical shock that is almost unique to the medical environment and is electrical shock from currents that are too small (20 - 140 –A) to be perceptible by persons whose skin is intact.
- In medical equipment there is typically a power transformer supplying low-voltage AC.
- Although the wiring to the transformer is insulated from the chassis, it is not necessarily true that it is isolated from the chassis and there will be a capacitance between them and some small AC current from the AC power lines to the chassis of the equipment.

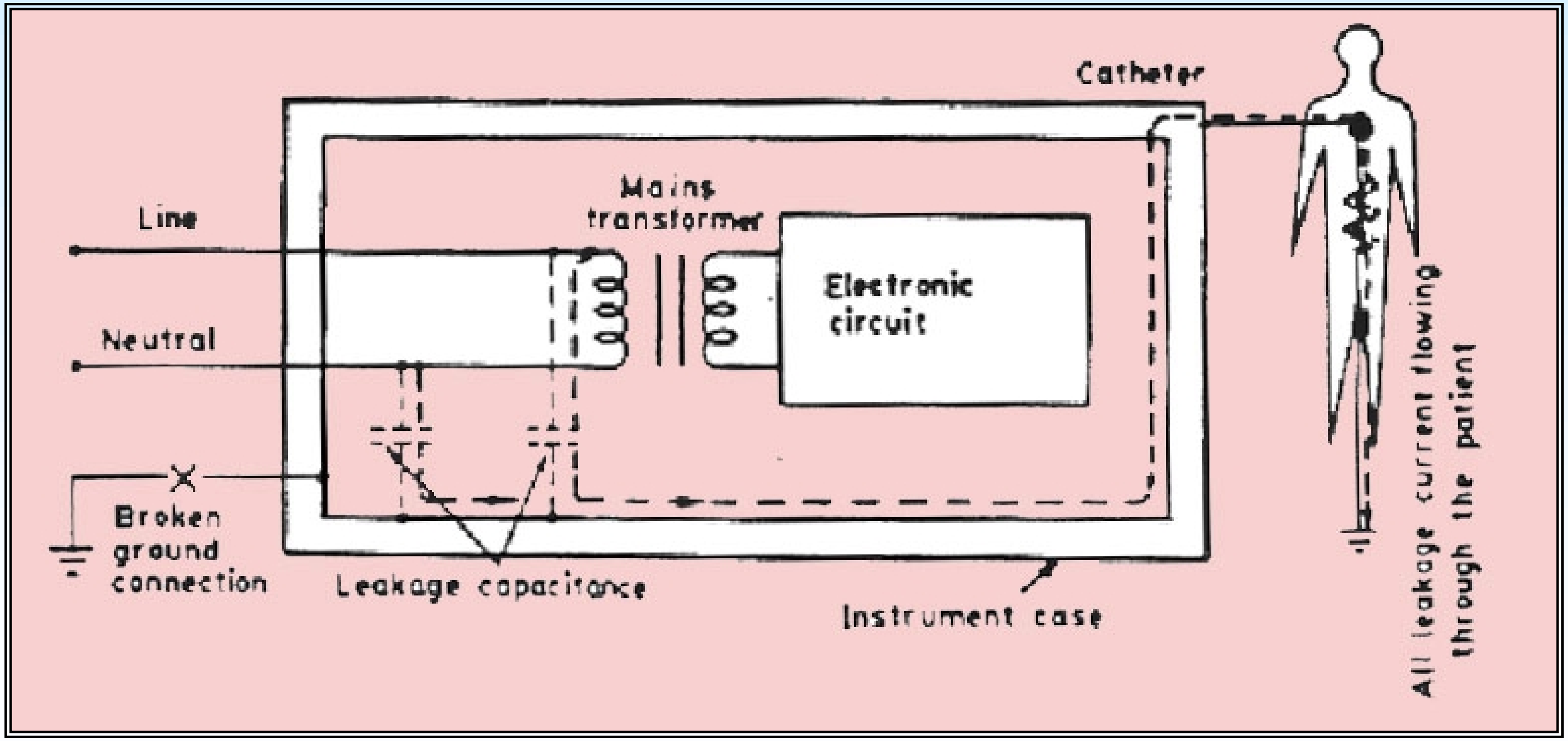
Leakage current

- This *leakage current* can drain harmlessly to the ground through the ground wire, unless it is broken or somehow defeated; then the path through the patient, if there is an accidental grounding of the patient.
- The safety standard for humans is set at 10 –A, an upper limit current, that seems not to provoke fatal ventricular fibrillation, passing through the sinoatrial node.

Low Resistance (1 Ohm) Ground Connection



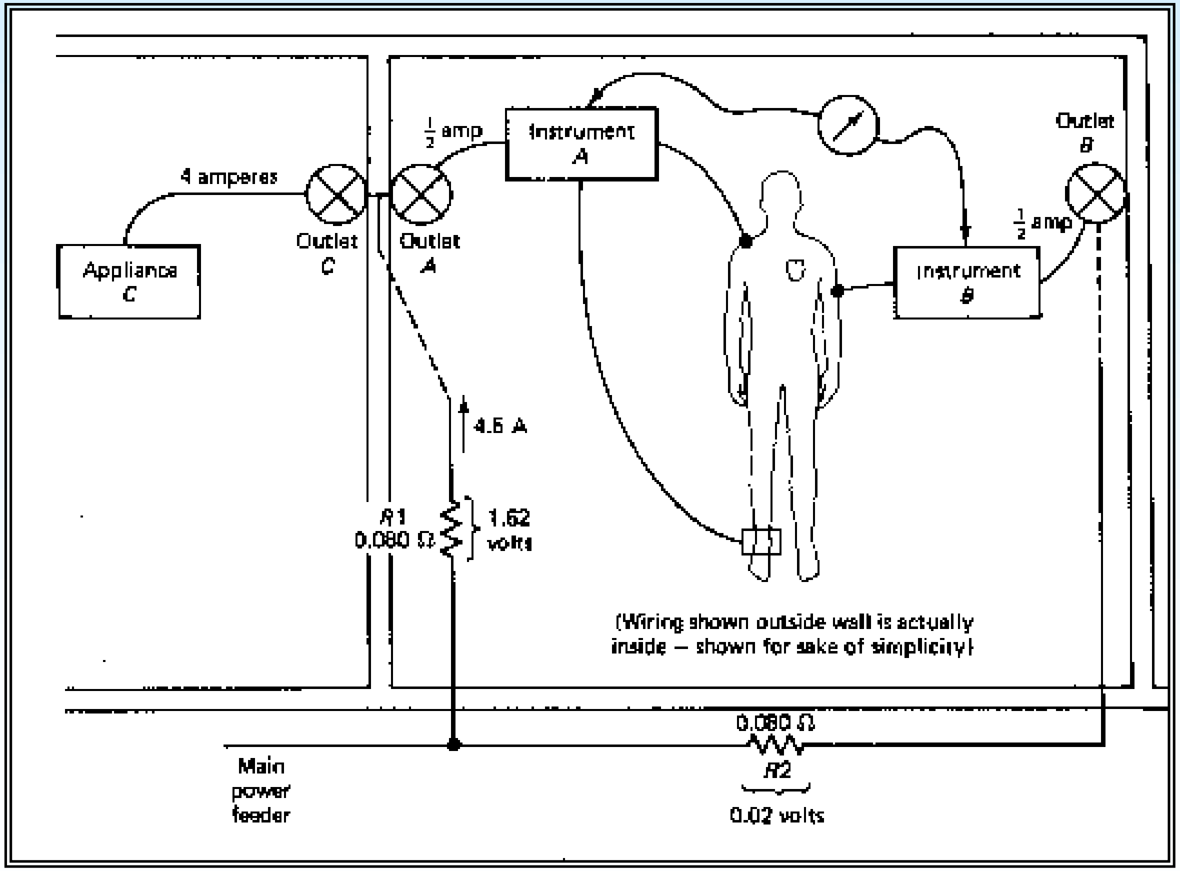
Broken Ground Connection



Side by side rooms

- In a situation in which two rooms are side by side, it is standard pracrtice that the lines to opposite sides are taken from different branches and that the same branch feeder is used on either side of a wall dividing two rooms.
- If a heavy appliance (4.0 A) is turned on in the same branch that feeds an electromedical equipment (0.5 A) and another equipment (0.5 A), feeded from the other branch, is applied on the patient, then, if the wiring resistance is 0.08 ohms the two devices on the patient are at a potential difference of at least 0.08 ohms x 4 A = 0.32 Volts, and the current that will flow through the 50 ohm patient resistance will be 6400 –A, considerably above the supposed safe value.

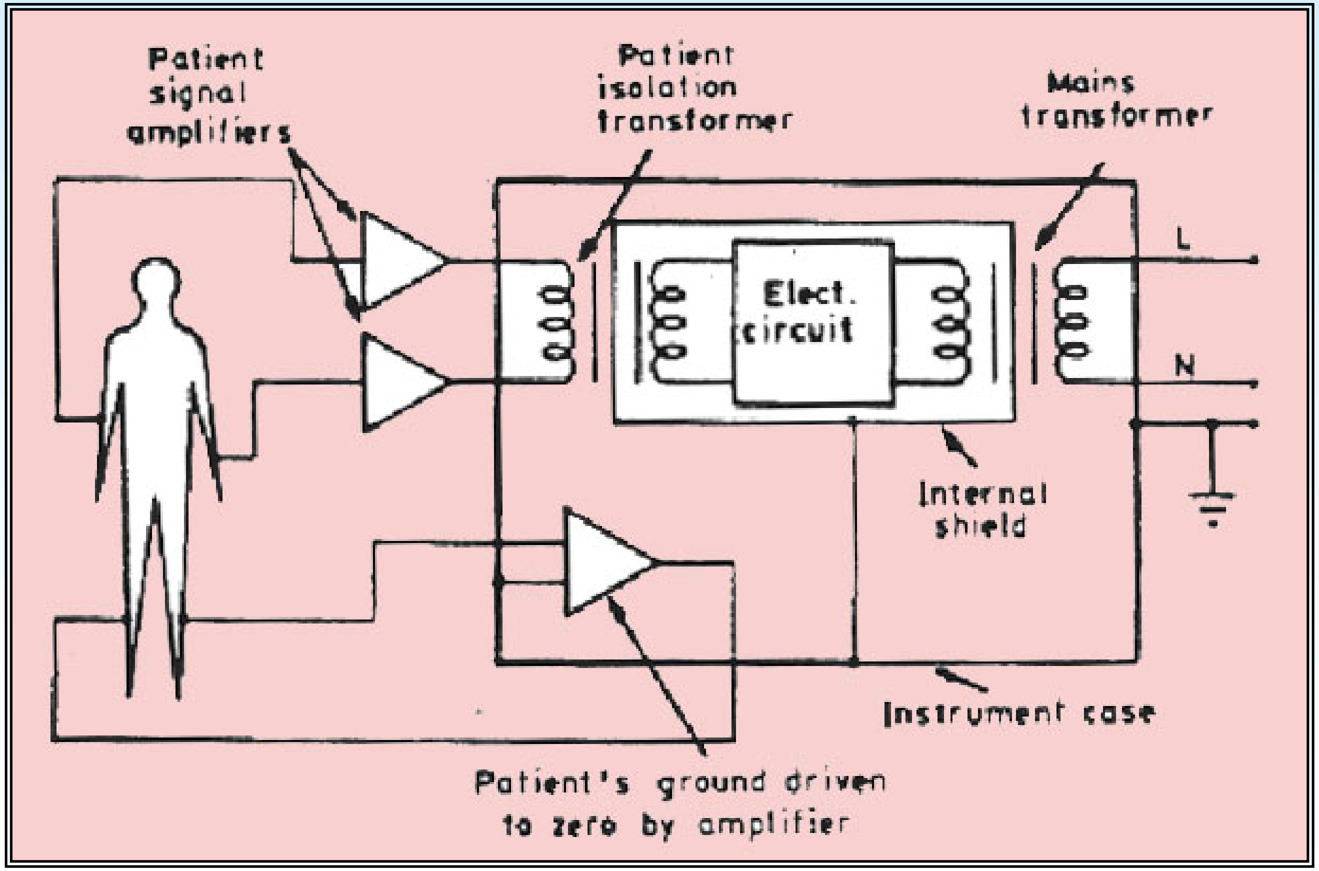
Heavy appliance in the same branch that feeds an electromedical equipment



Isolation transformer with separate patient ground drive

- The next improvement in matters of safety is removing the patient ground connection by replacing it with an operational amplifier in a feedback loop.
- The patient ground is assumed to be floating at some safe level which is detected by the amplifier and driven back down to zero level.
- When the current limitation of the amplifier is exceeded, it ceases to function, but the patient is not connected to ground.

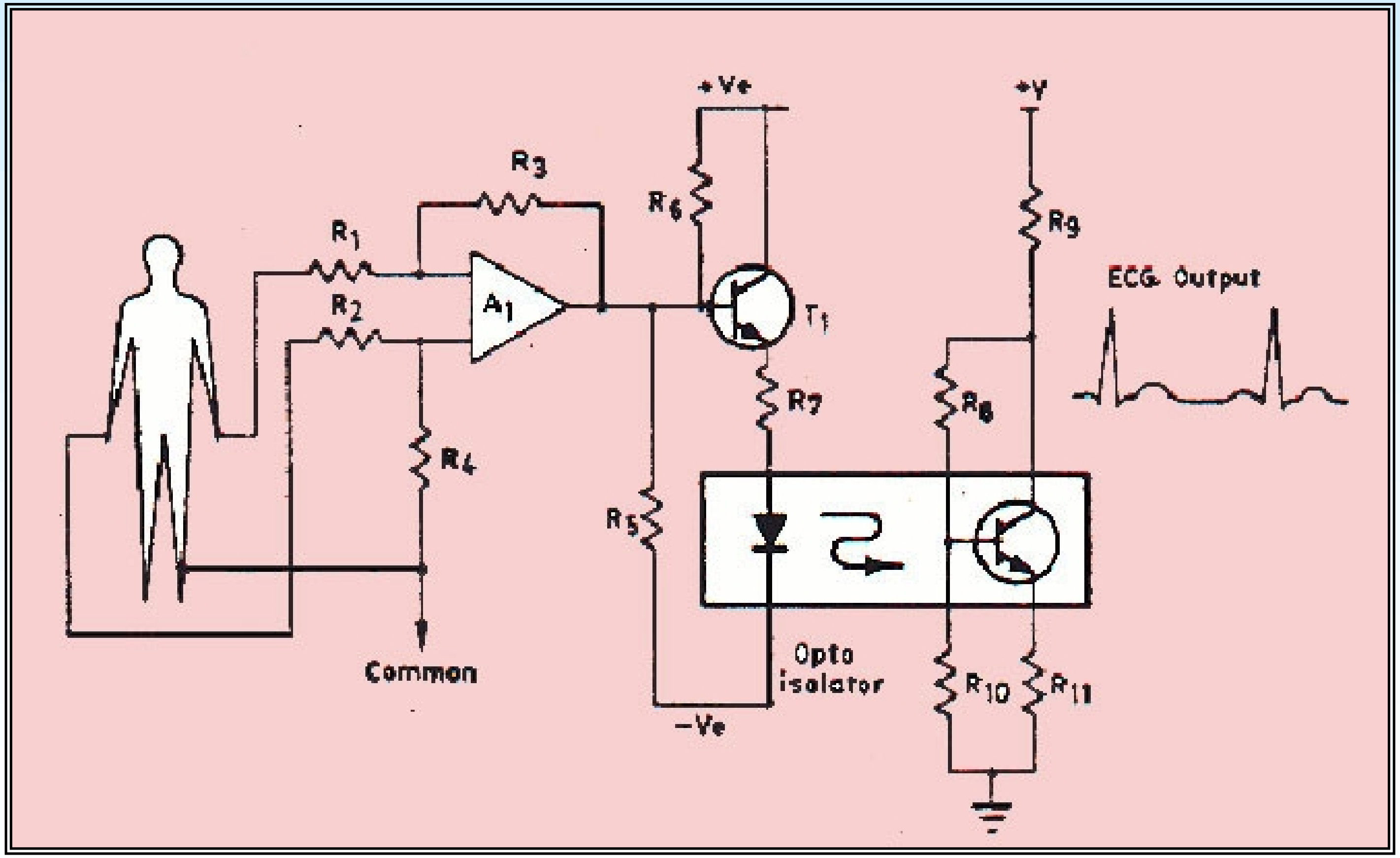
Inductive Coupling



Optical isolation of the patient

- Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line. A separate battery operated circuit supplies power to the patient circuit and the signal of interest is converted into light by a light source accurately calibrated in frequency and magnitude. This light falls on a photodiode which converts the light signal again into electrical signal having its original frequency, amplitude and linearity.
- Instruments such as electrocardiographs, pressure monitors, pressure transducer, pacemakers and others have been designed to electrically separate the portion of the circuit to which the patient is connected from the portion of the circuit connected to the ac power line and ground.

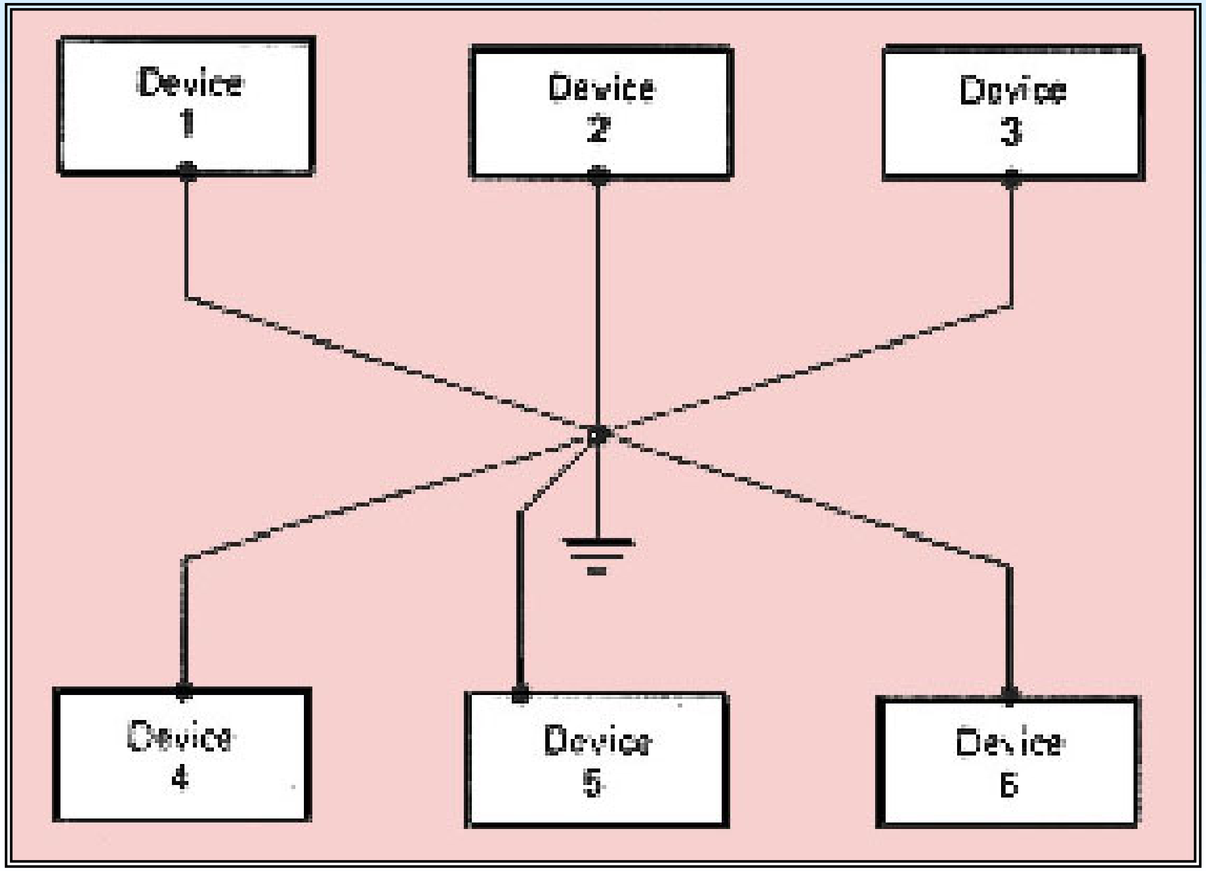
Optocoupling



Equipontential ground system

- In this case, we are using the normal hospital electrical system, but have provided redundant grounds, to back up the grounds in the power cord, that are connected to a large metal plate.
- Every instrument, appliance, or device, including the patient's bed, is connected to the equipotential ground and the common ground bus plate is, in turn, connected to the hospital power system ground bus.
- This method of protection is common in coronary care units (CCU) and intensive care units (ICU) of hospitals, and eliminate the hazard of voltage difference appearance between various equipment.

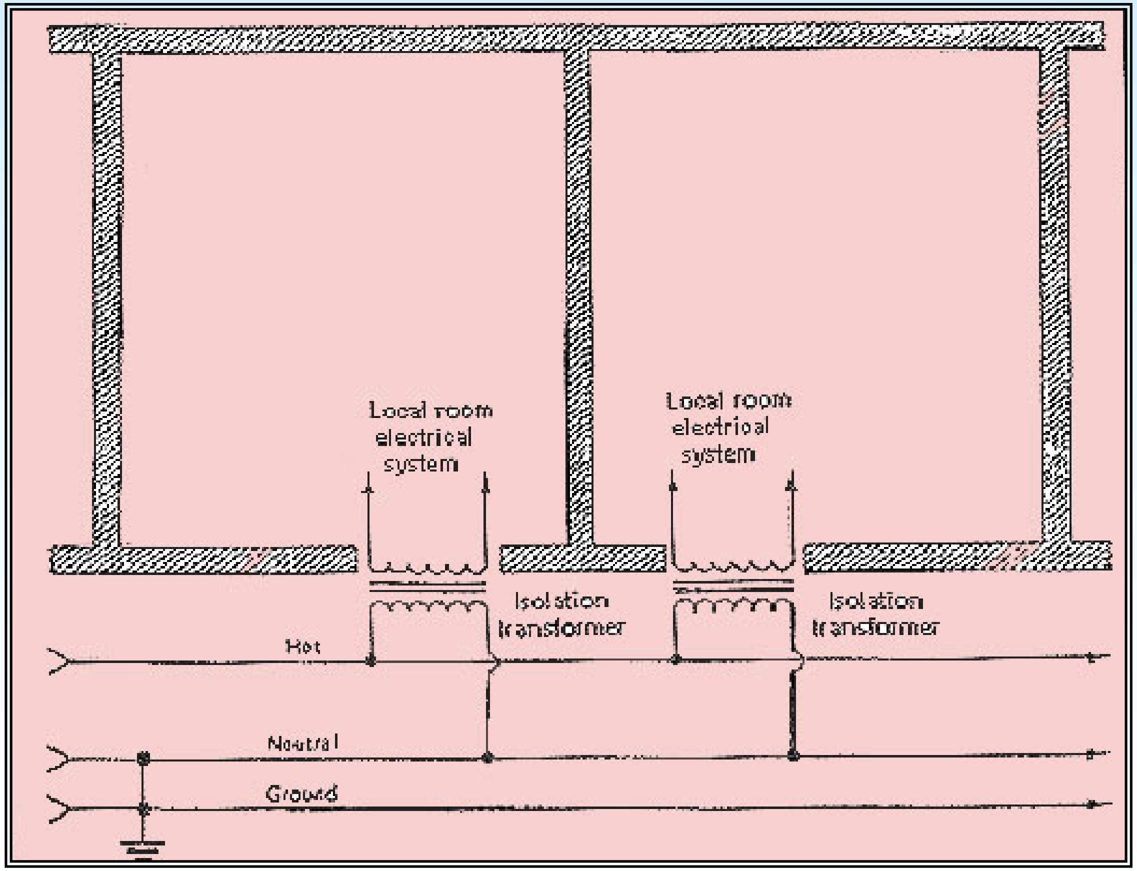
Equipotential Earthing System



Isolated electrical Systems

- The main hospital electrical system uses the standard three-wire distribution system: hot, neutral and ground.
- These wires are not sent to the room, but connect to an isolation transformer.
- All branch circuits in the room are fed from the secondary winding of this transformer, isolating the local room power system, and providing two lines floating above the ground, thus, eliminating the leakage current problem.
- This system is common in operating rooms and the trauma rooms of emergency department.

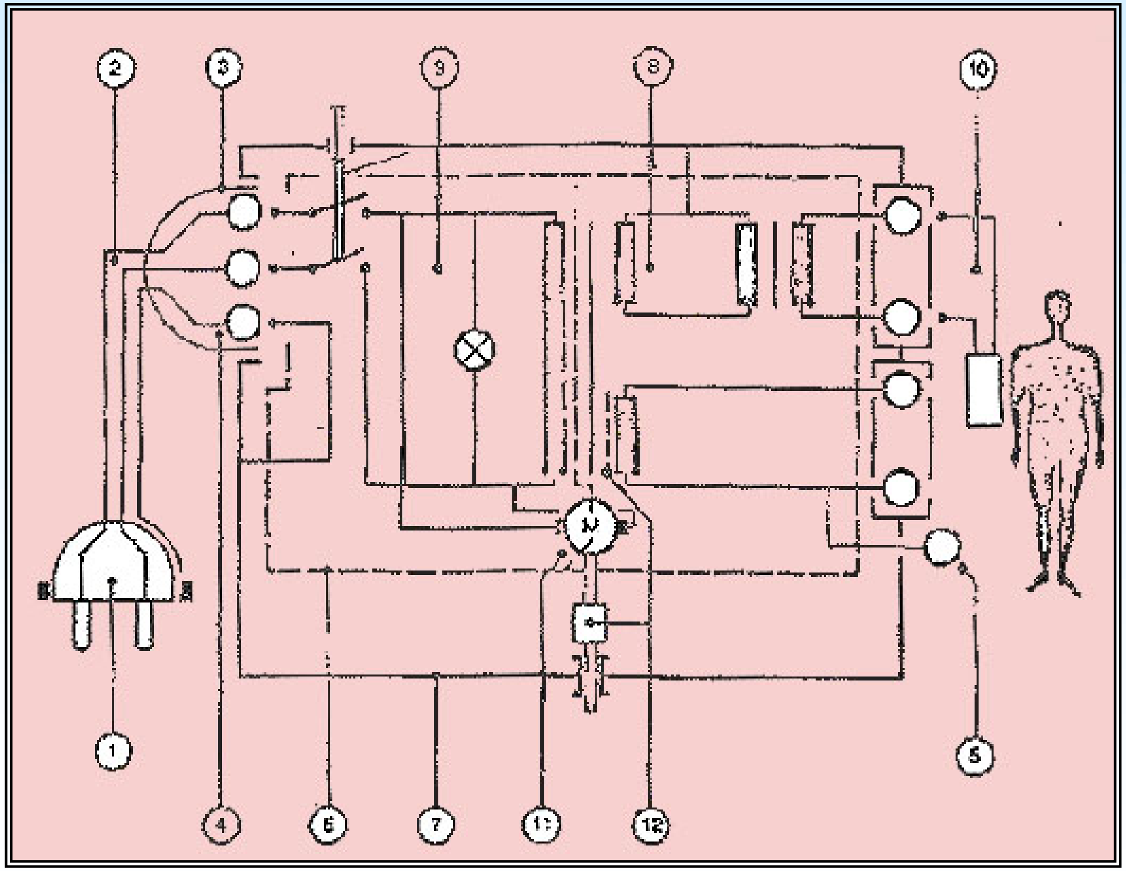
Isolation Transformers



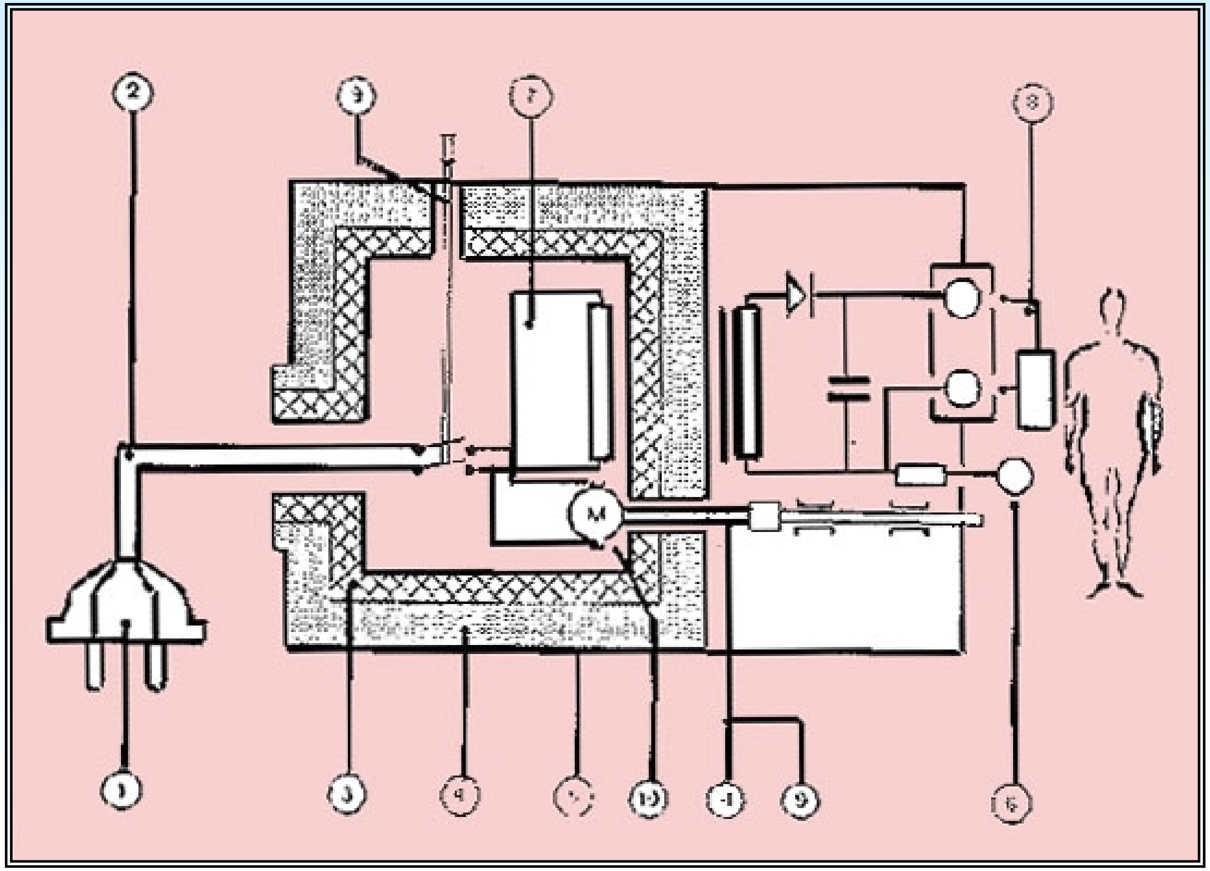
Class I-II Equipment

- **Class I Equipment:** Equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in that means are provided for the connection of the equipment to the protective earth conductor in the fixed wiring of the installation in such a way that accessible metal parts cannot become live in the event of a failure of the basic insulation.
- **Class II Equipment:** Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions.

Electrical Insulation Class I



Electrical Insulation Class II



Tests to be carried out periodically on electromedical Equpment

- Measurement of leakage current and ground resistance constitute majority of the tests and must be carried out periodically on instruments normally applied to the patients.
- A general safety principle envisages that at least two means for protection shall be provided in the equipment, except only in those cases where single fault condition, will not give rise to a dangerous situation.
- The condition in which one form of protection against electric shock is inoperative is termed a *single fault condition* (SFC).

Tests according to the IEC 601.1

Following test are usually performed, according to the IEC 601.1 regulation during an electrical safety equipment inspection:

- *Insulation Resistance (Mains and Applied Part).*
- *Earth Continuity.*
- *Earth Leakage Current (Normal & SFC).*
- *Enclosure Leakage Current (Normal & SFC).*
- *Patient Leakage Current (Normal & SFC).*
- *Patient Auxiliary Current (Normal & SFC).*
- *Mains on Applied Part.*

Electrical Safety Measurements in Greek Hospitals

- Electrical Safety Measurements have been carried out according to IEC 601.1 of some important Greek Hospitals (*Evangelismos Hospital, Athens, Metaxa Hospital, Piraeus, Sismanogleion Hospital, Athens, University Hospital, Patras).* The above Hospitals, with over 2500 beds in all, constitute a representative sample of the the major Greek Teaching Hospitals.
- The measurements have been carried out, according to the IEC 601.1 regulation and all the above mentioned parameters have been measured.

Testing devices

The following commercially available testing devices were used, for the assessment of the electrical safety features of the Intensive Medicine Equipment of the above mentioned Hospitals:

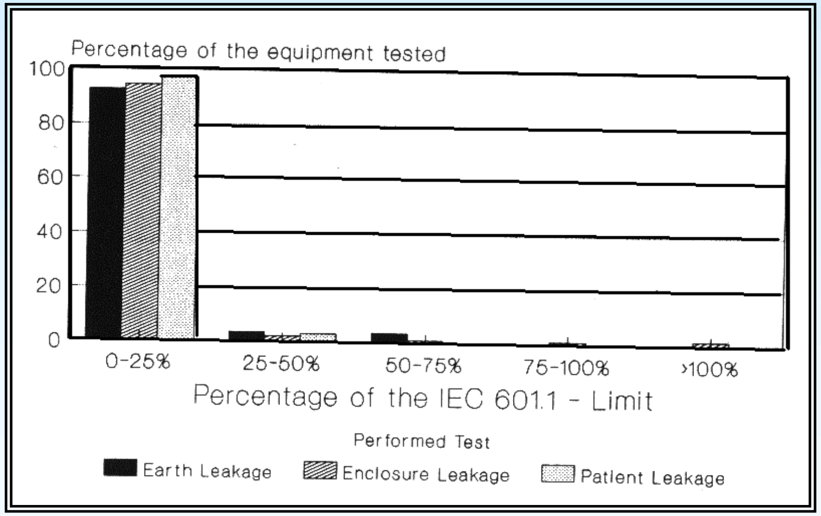
- *Three standard Electrical Safety Analyzers (BIOTEK 470).*
- *One Microprocessor based Electrical Safety Tester with integrated printer (BENDER).*
- *Two Defibrillator Energy and Time - Delay Analyzers (BIOTEK).*
- *An Electromagnetic Interference Monitor (METRON).*

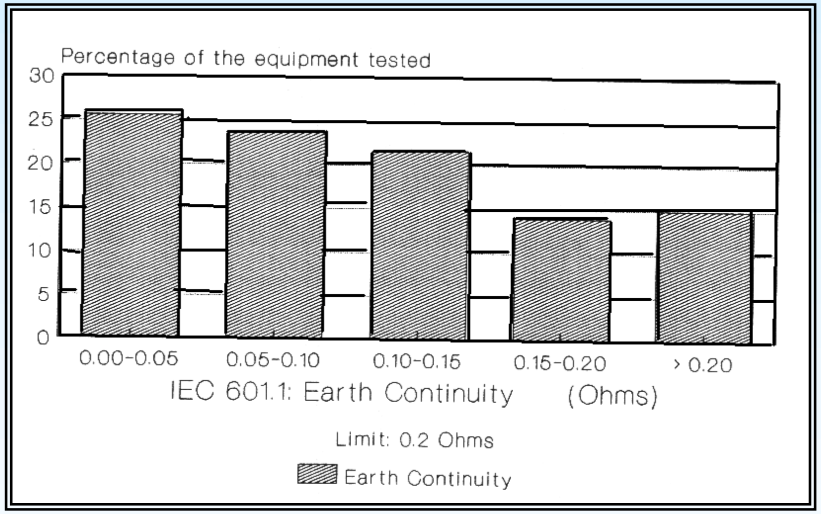
Test Results

Over 200 Cardioscopes and Monitoring Equipment, as well as 50 Defibrillators have been tested:

- *The Enclosure Leakage Current measured, of 1.5% of the tested equipment, exceeded the IEC 601.1 limits.*
- *The Resistance measured during, Earth Continuity Tests, of 15% of the tested equipment, exceeded the limit (i.e. 0.2 Ohms), because of damaged 220 VAC Mains - Connectors.*
- *No further deviations from the IEC 601.1 limits have been detected.*

Electrical Safety Measurements

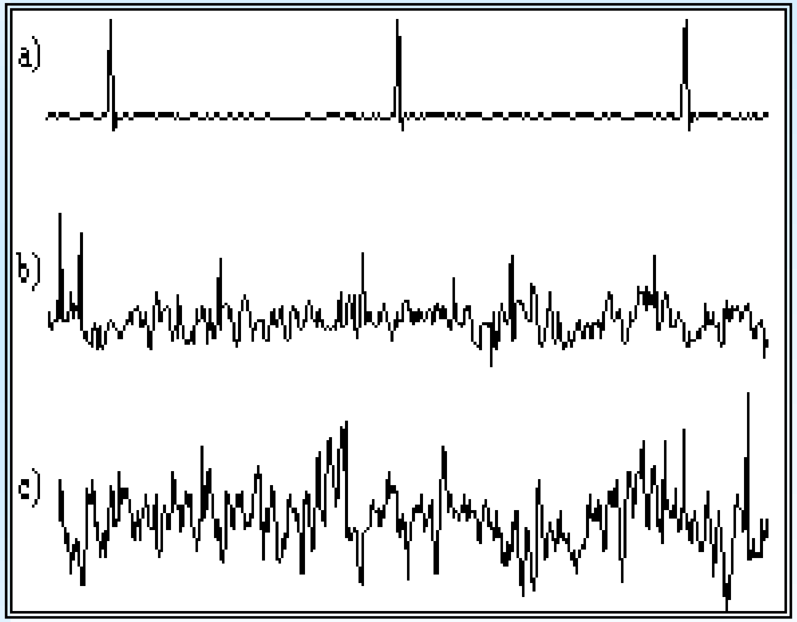




Distribution of the Earth, Enclosure, Patient Leakage, and Earth Continuity measurements

Typical Defibrillator

Defibrillator Recordings

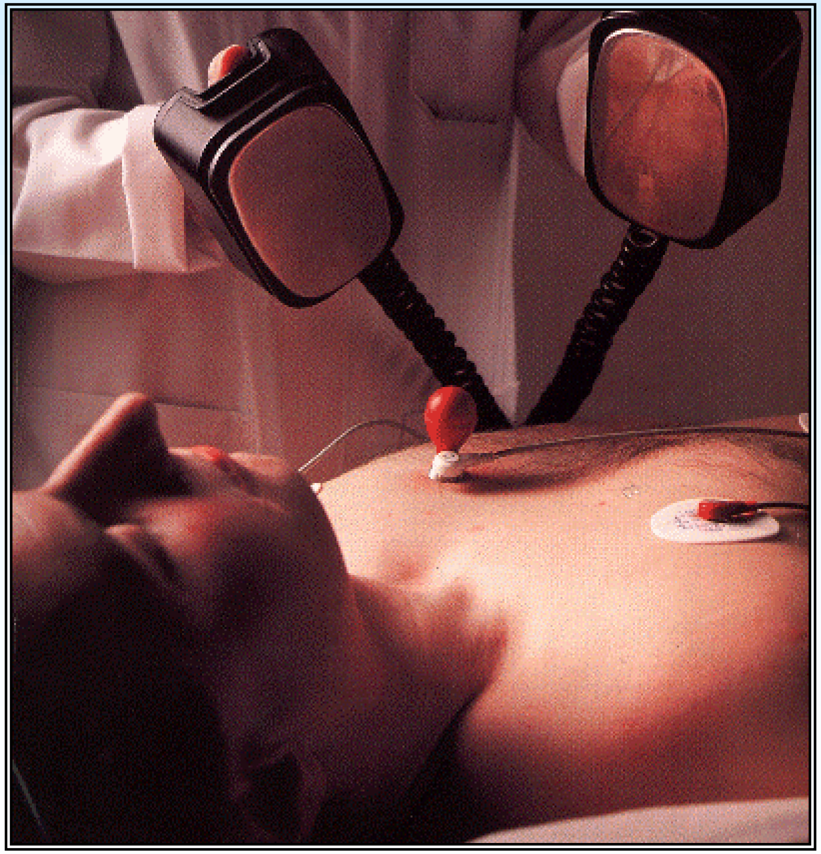


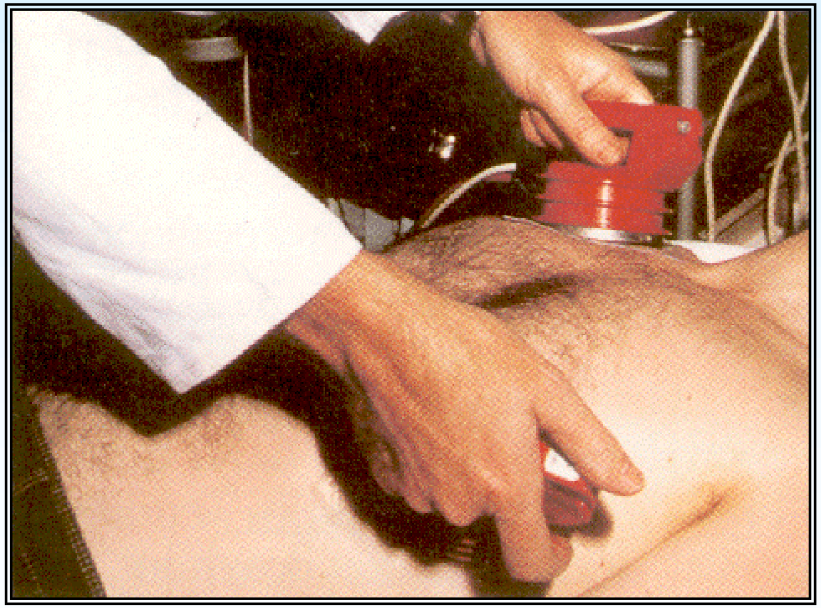
a. Sinus Rhythm
b. V. Tachycardia
c. V. Fibrillation

Defibrillator Safety Tests

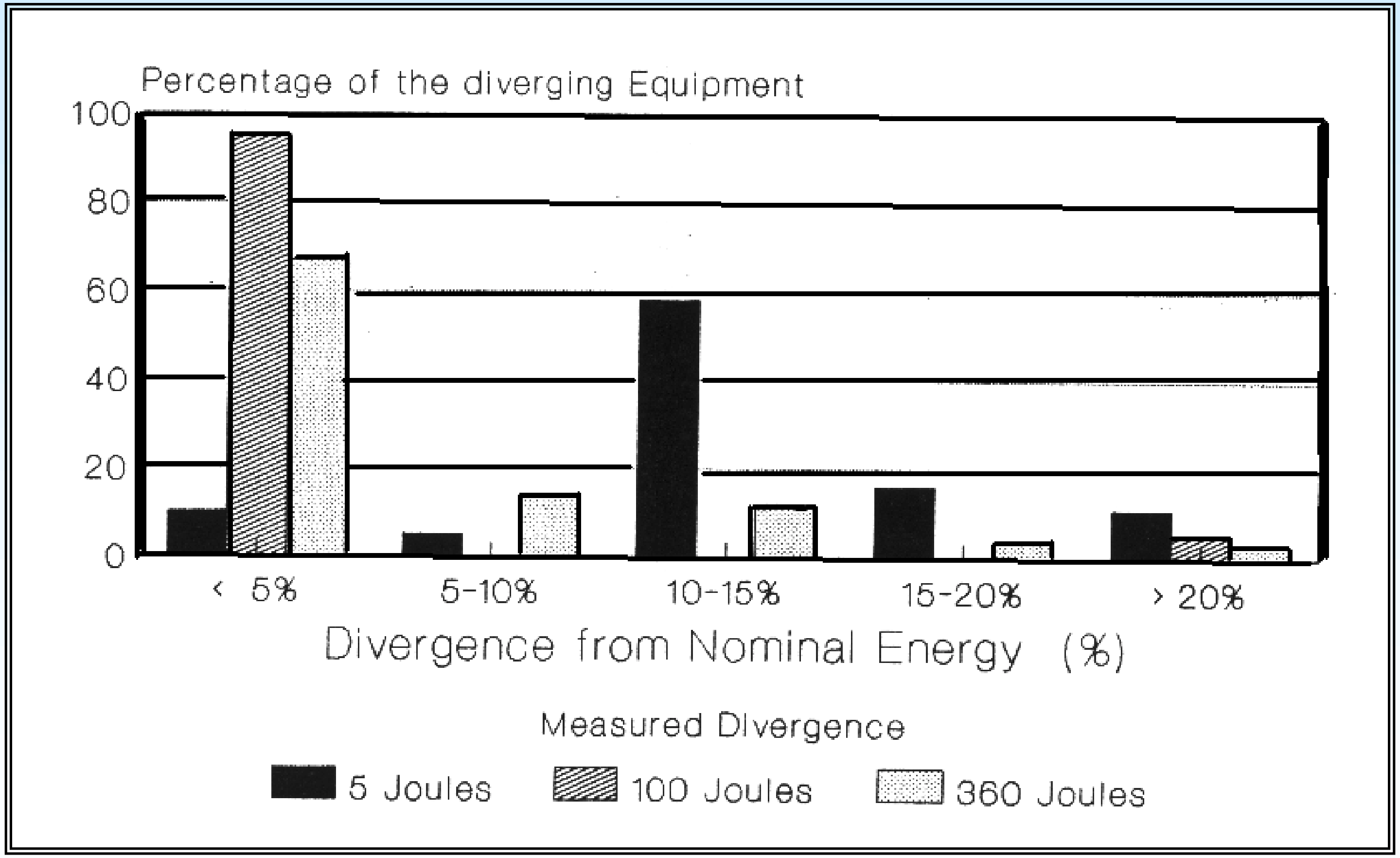
- The Energy Output of the defibrillators tested showed high deviation, between nominal and measured energy values, in the Low Energy Range (5 Joules).
- Only 10% of the tested equipment showed deviation of less than 5%, since the rest, showed a deviation between 10% and 20%.
- In the Middle Energy Range (100 Joules), 95% of the tested equipment showed a deviation, between nominal and measured energy values, of less than 5% and in the High Energy Range (360 Joules), 90% of the tested equipment, showed a deviation of less than 10%.

Defibrillator Safety Tests
(Energy and R-wave synchronization)





Defibrillator Energy Test Results



Energy Output deviation, between nominal and measured Energy values of the Defibrillators tested

Magnetic Field Intensity Measurements

- Induced Magnetic Field Values have been measured in critical areas (e.g. EMG & EEG - Rooms, Operating Rooms etc.).
- The Magnetic Field Intensity Measurements in critical Hospital areas and the produced *equal intensity curves* have shown, that in several cases, the measured values exceeded the requirements, according to IEC 601.1 i.e.
  - *EEG: 19x10-8 Tesla.*
  - *ECG: 38x10-8 Tesla.*
  - *EMG: 300x10-8 Tesla.*

Electrical Safety in Major Greek Hospitals: Conclusions

- The results of this investigation, form a representative image of the present situation, concerning Electrical Safety in Major Greek Hospitals.
- Obviously, the situation is acceptable, but there is an urgent need, for periodical performance of Safety Tests and for an elementary "safety maintenance", in order to eliminate the very low, but still existing, residual patient risk.

Patient Data and Statistics

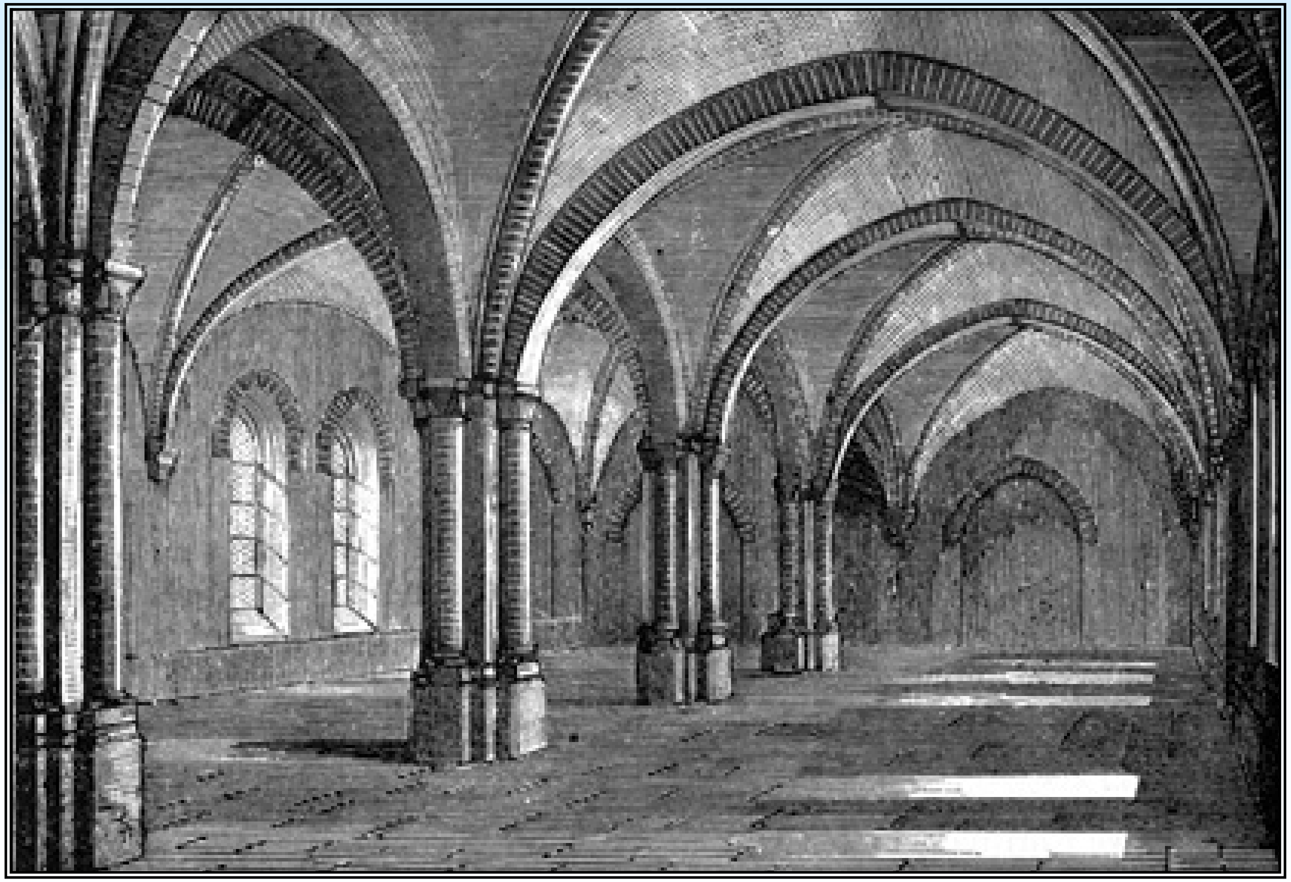
- Computerized Data Management is becoming common and the ICU should be fitted into a Hospital Information System if available.
- Otherwise, local systems can enable present data management and future integration.
- Artificial Intelligence systems have also made their appearance in the ICU, supporting monitoring, evaluation and treatment of the patient.

The future of the ICU

- The number of the ICU beds in the modern Hospitals is increasing dramatically *(Brigham and Women's Hospital, Boston, MA, shows a ratio of 250/800)*.
- Contemporary Technology allows for setting up an ICU on any site, even at home, in a hotel or on aboard of a ship.
- Decision Supporting Systems will play an important role in the ICU.

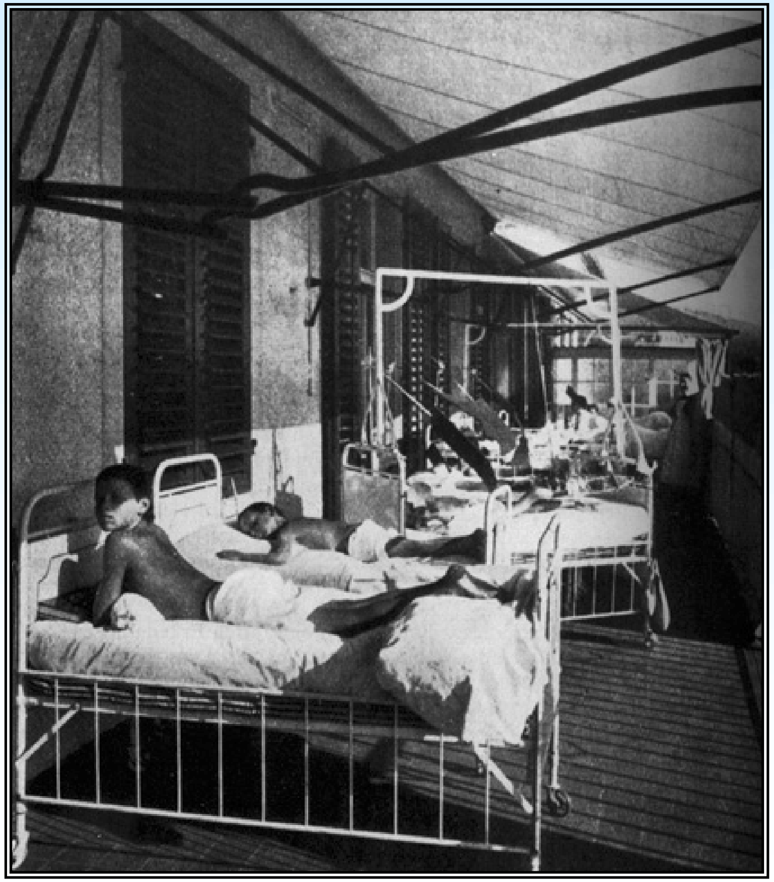
The Patient Wards

Domus sancti spiritus: Copenhagen 1649

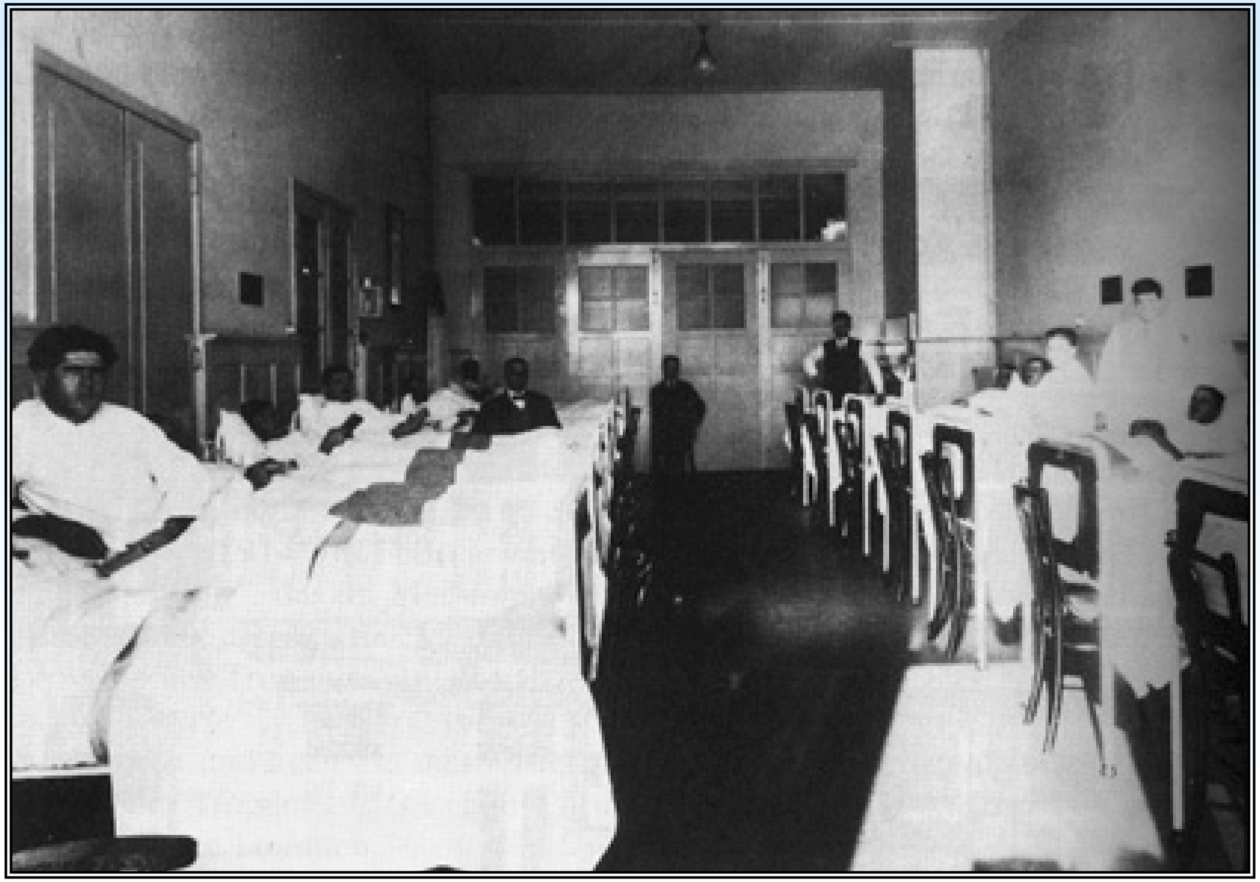


Hamburg Maritime Hospital 1901

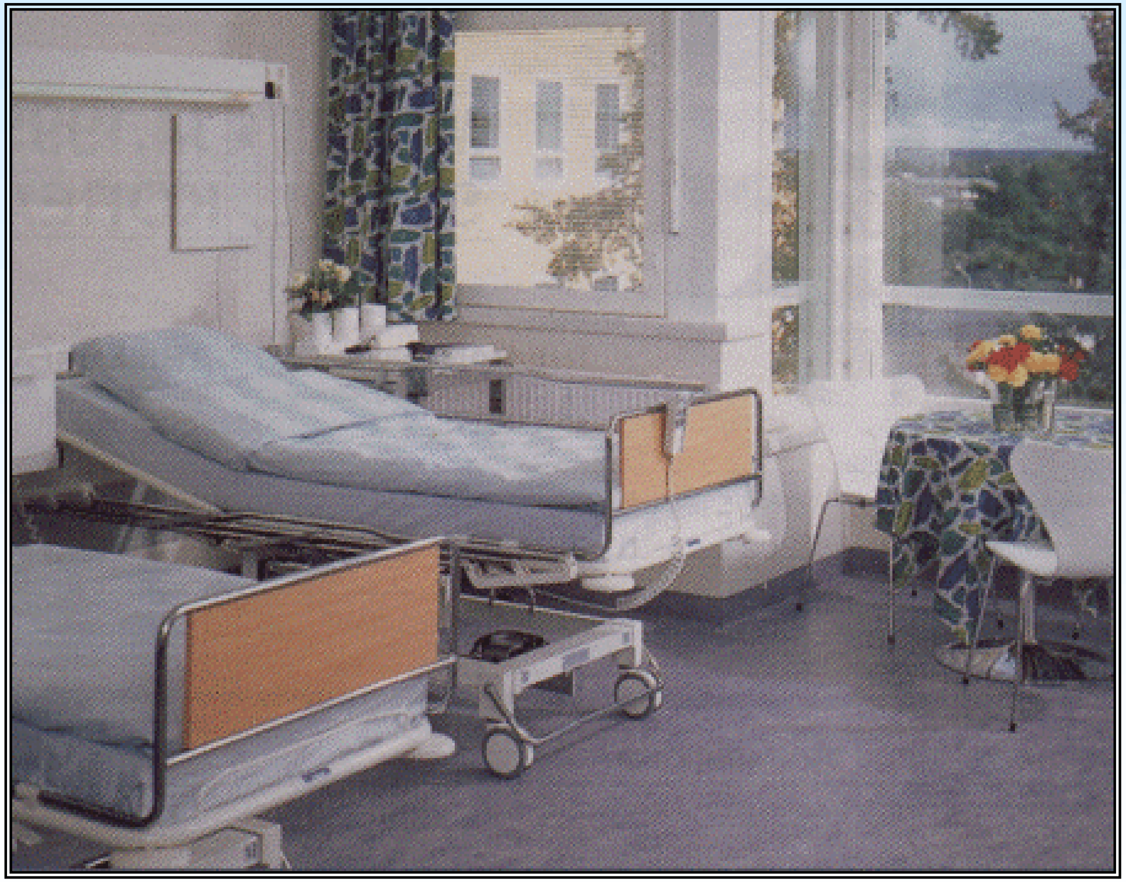
Balgrist Children Sanatorium, Switzerland 1911



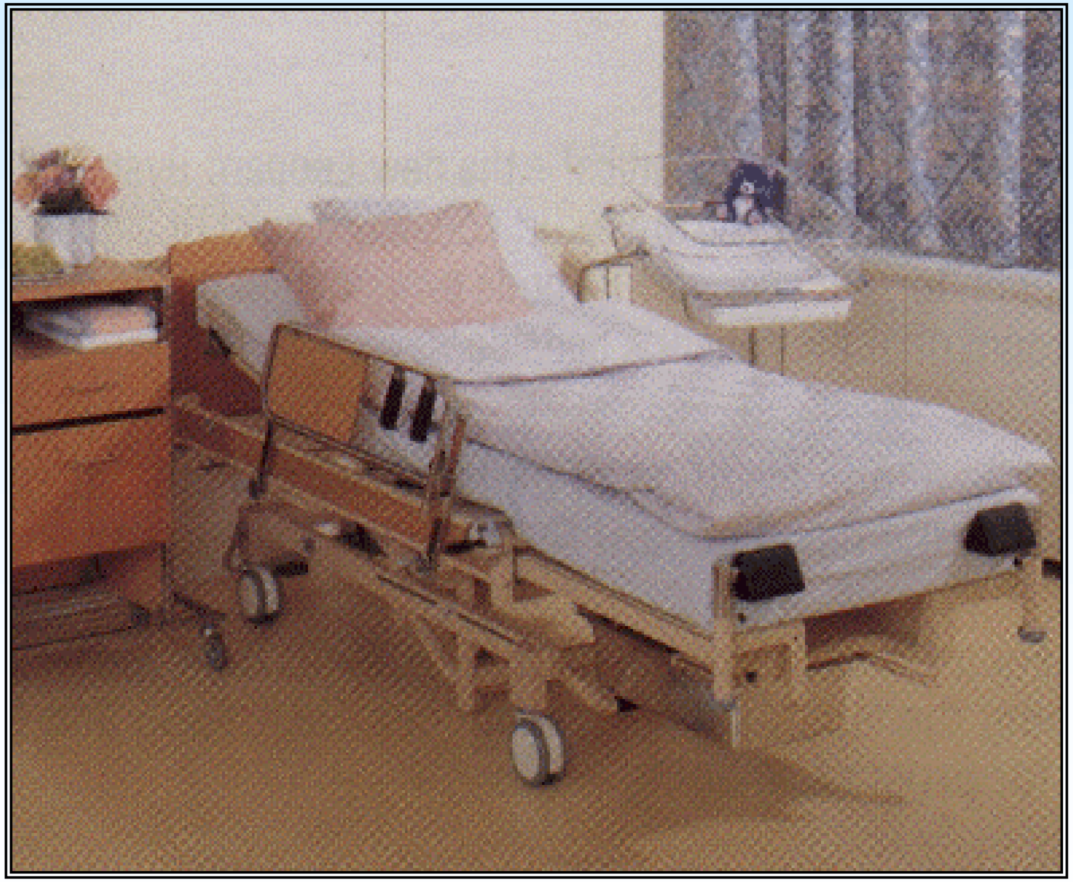
Port Hospital, Rotterdam, Holland, 1927



Modern Patient Room

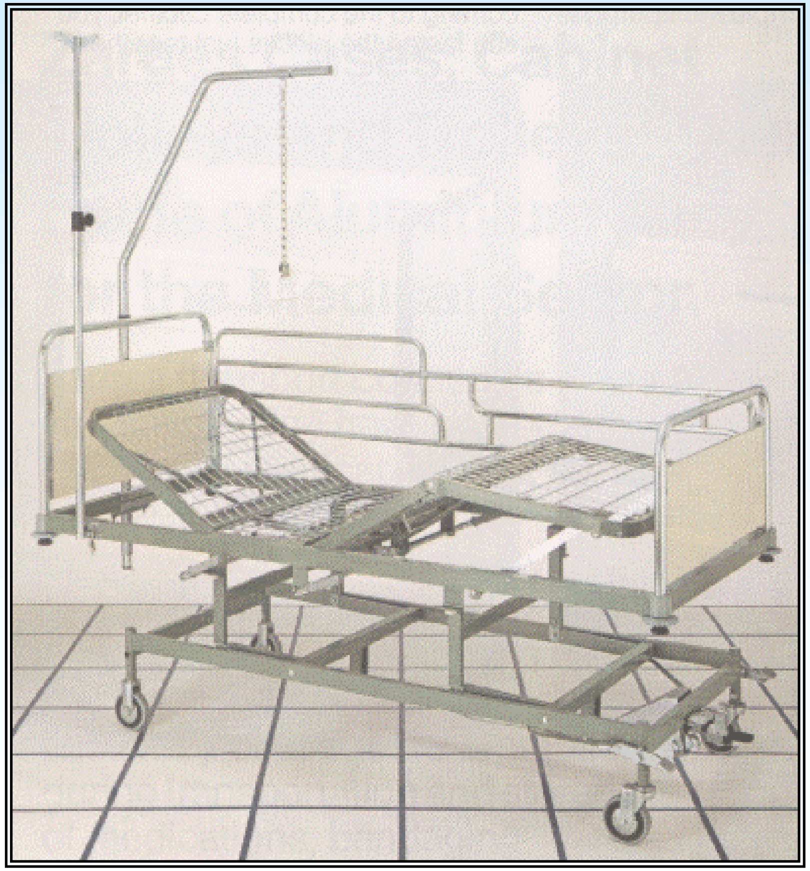


Typical Ward Bed



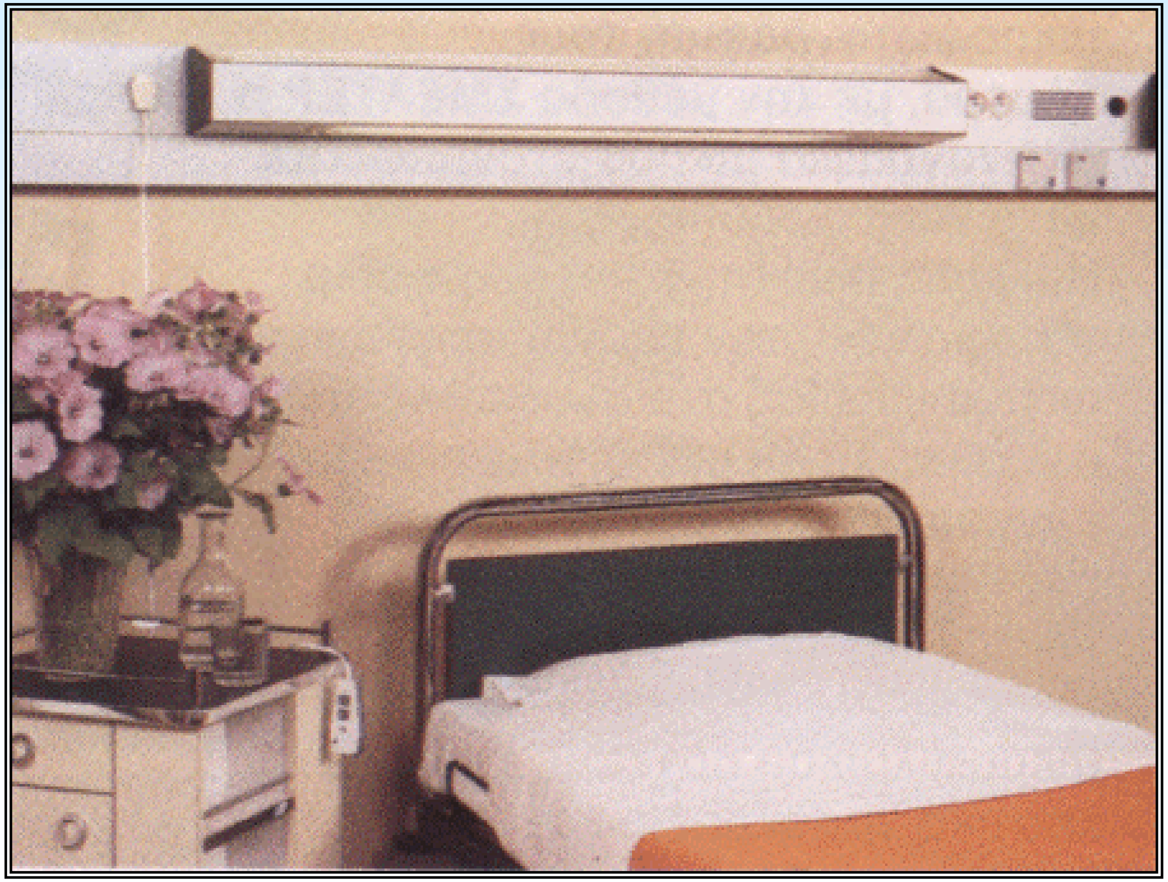
Technical Details of a Ward Bed

Usual Bed Accessories

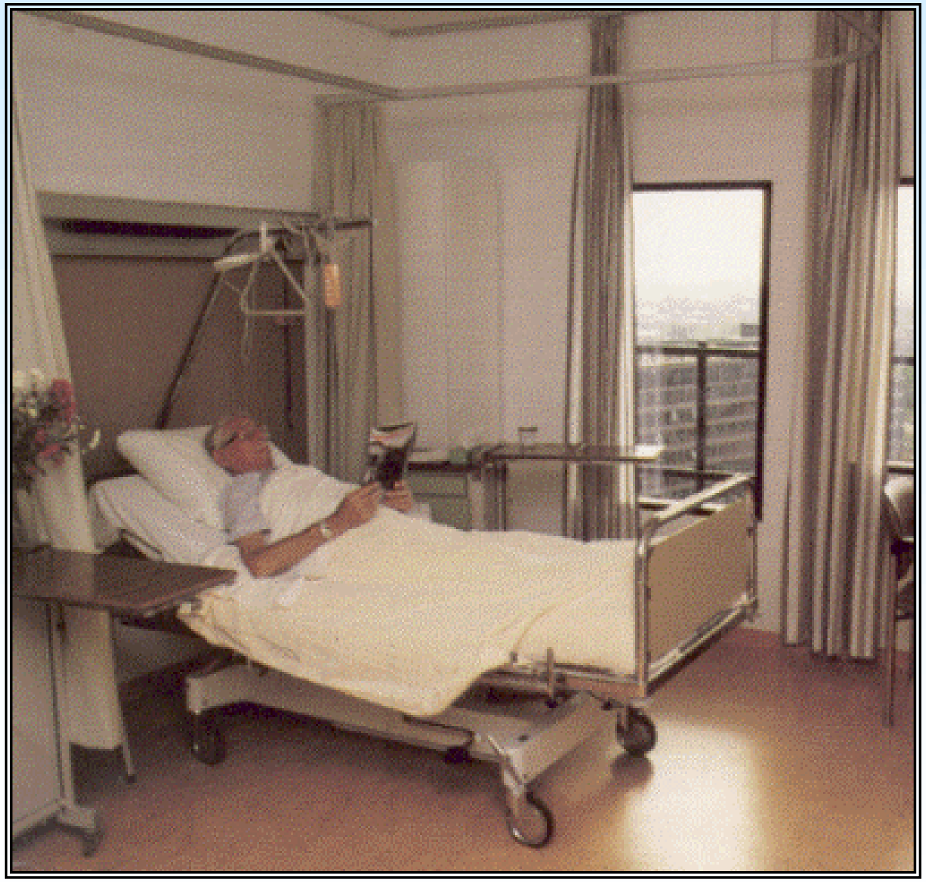


Bed-head Units

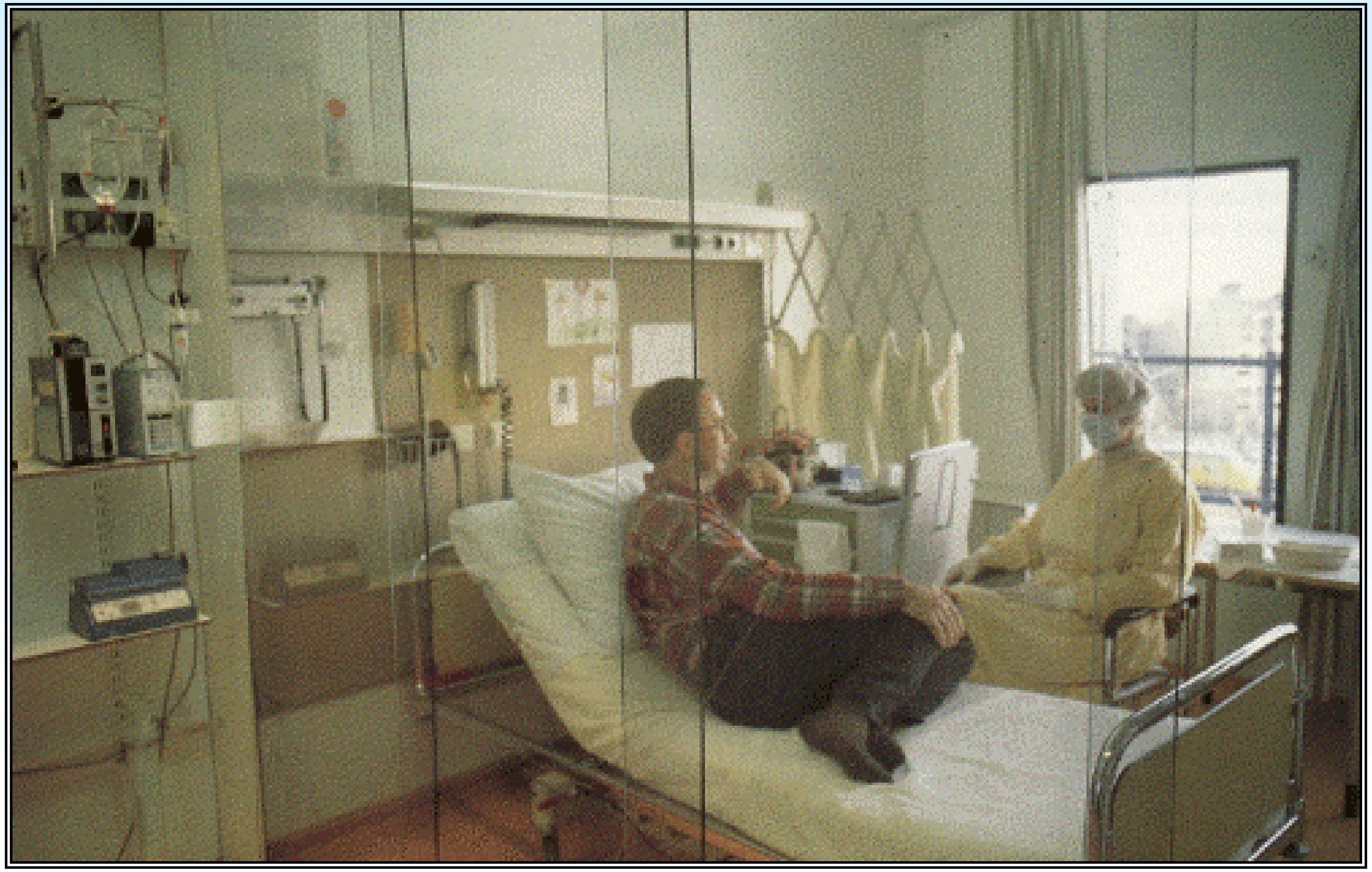
Bed-head Unit and bedside table



Patient movement support

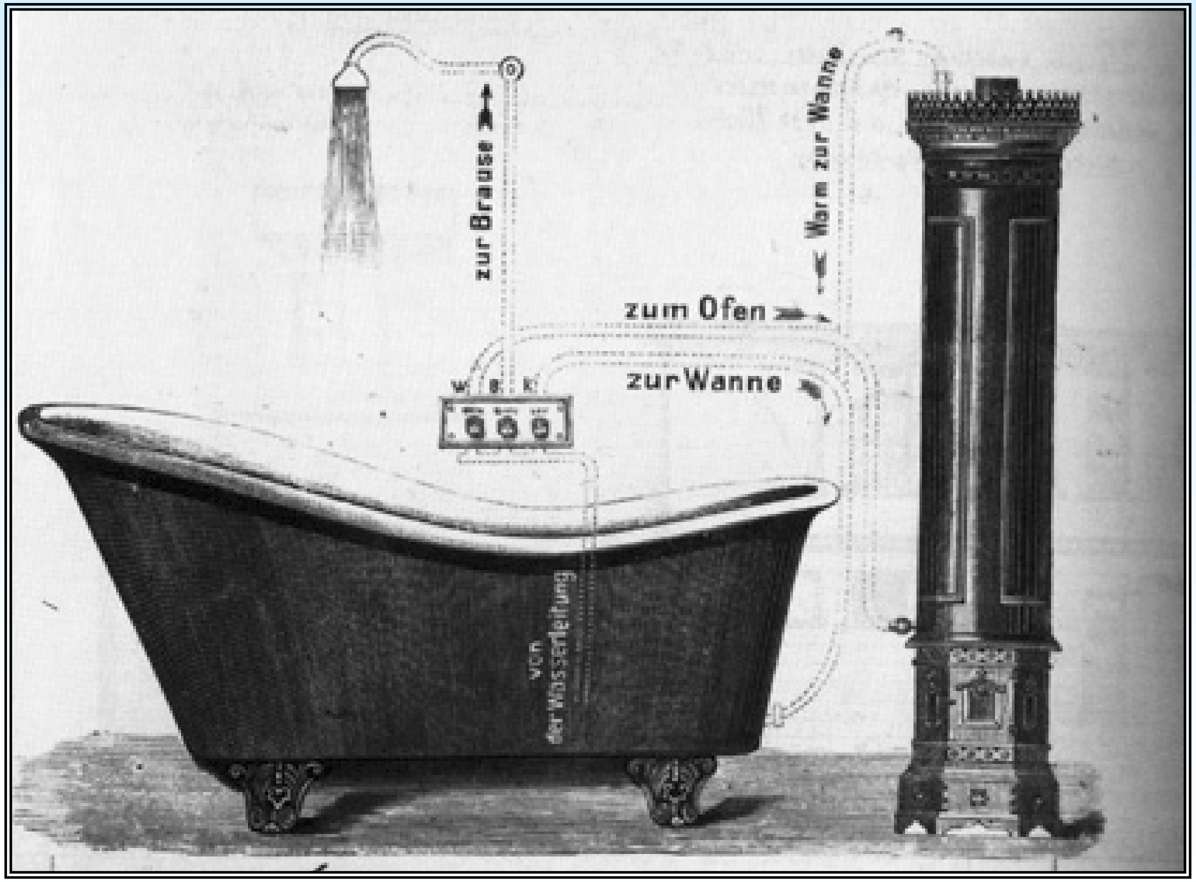


Isolation Room in an Increased Care Room (e.g. Immuno-deficient Patients)



Children Ward

Sanitary Ward Equipment
Minden, Germany, 1888

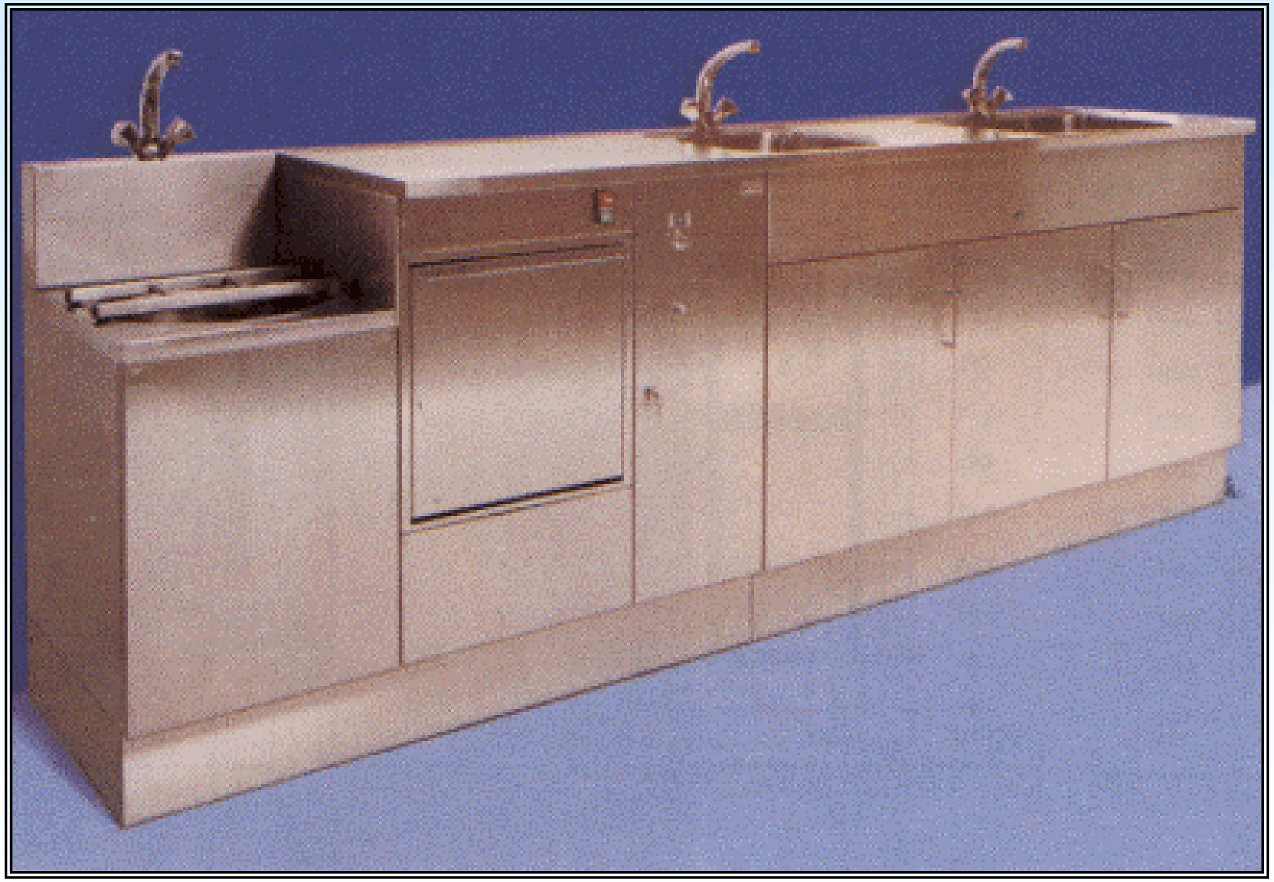


Sanitary Installations and Items

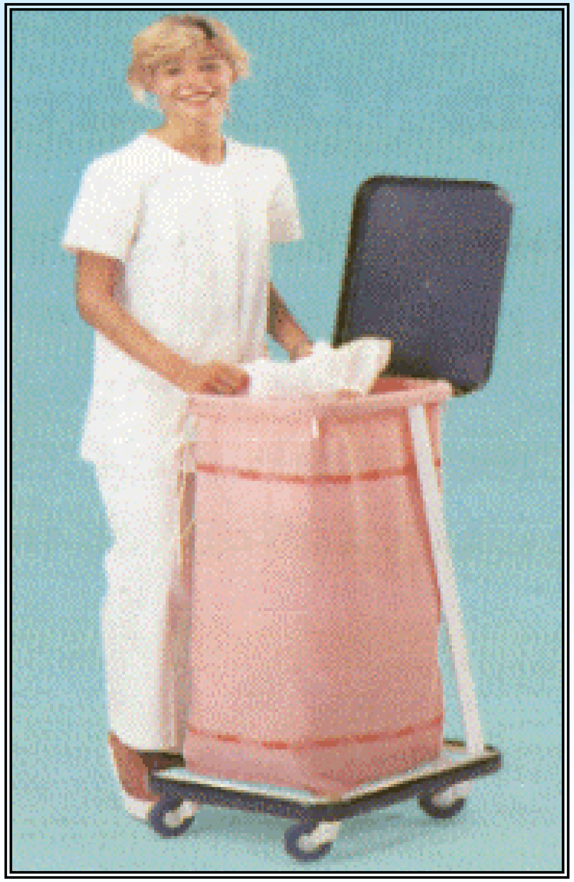
Bed-pan and Urine-bottle Washer

Utensils Dryer

Sanitary Room in a Nursing Ward



Bed-linen transport



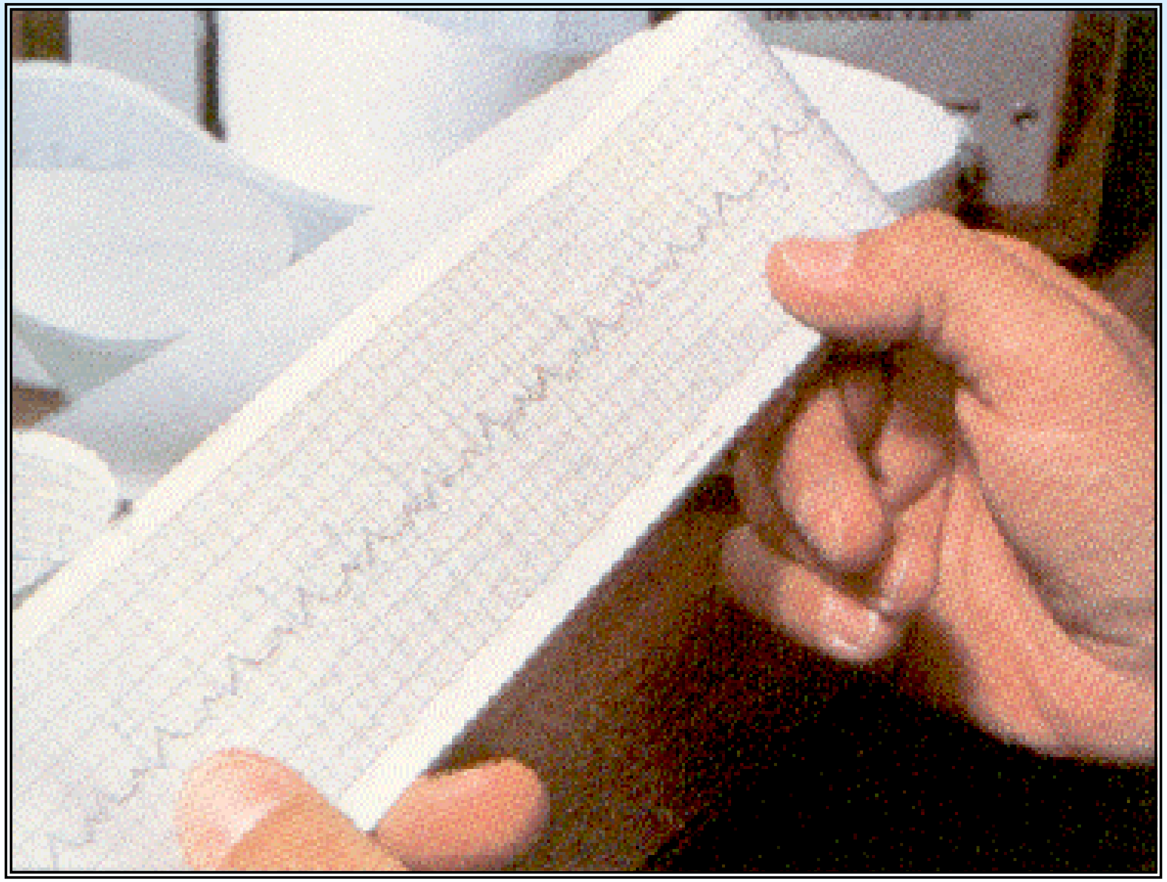
Solid Waste Collection

Liquid Waste Collection

Rubbish collection and sorting

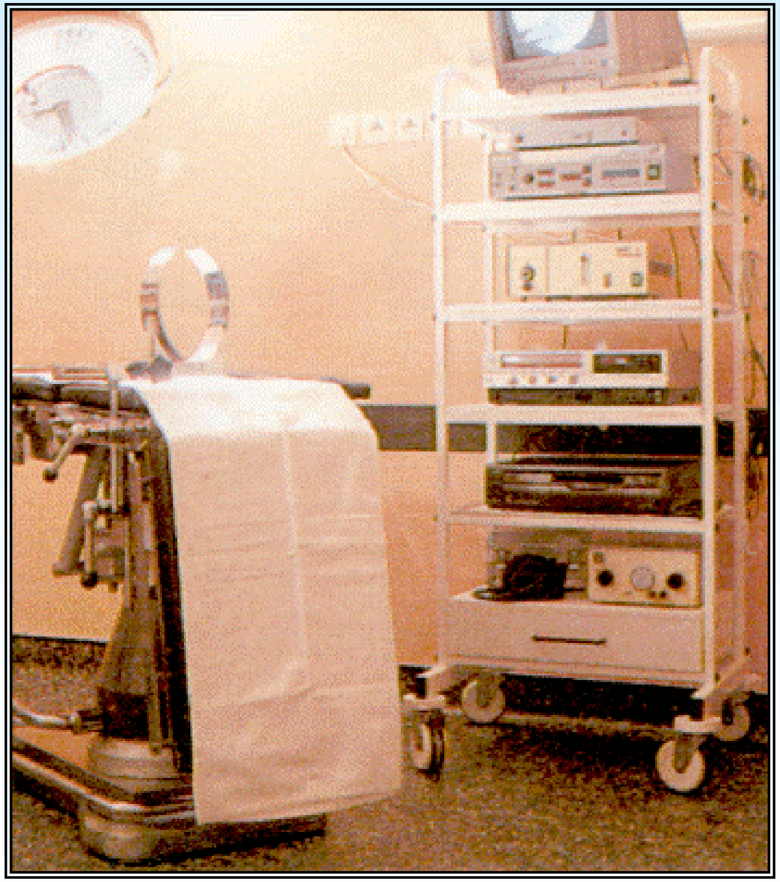
Janitor’s Cart

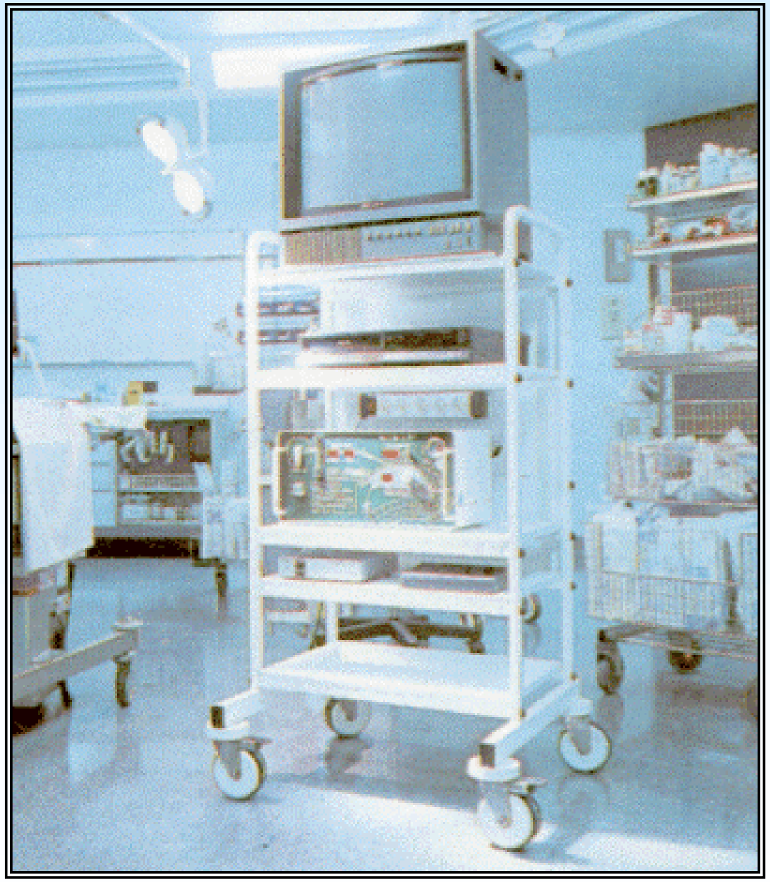
Nursing



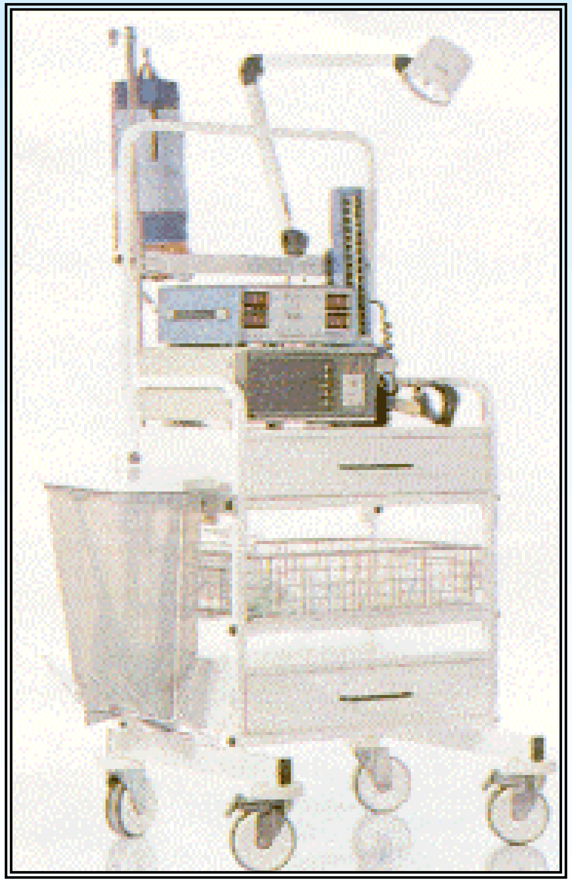
Mobile Nursing Tables on castors

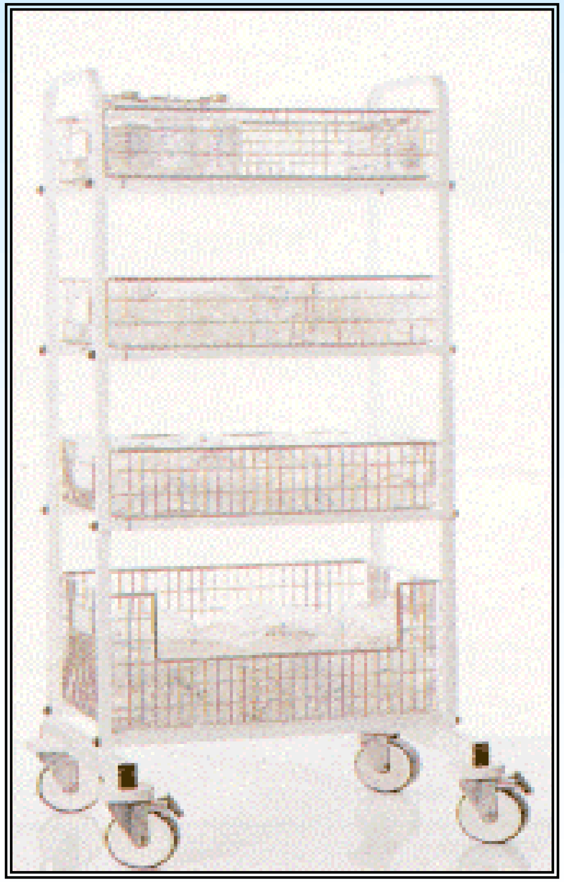
Examination Rooms in the Wards



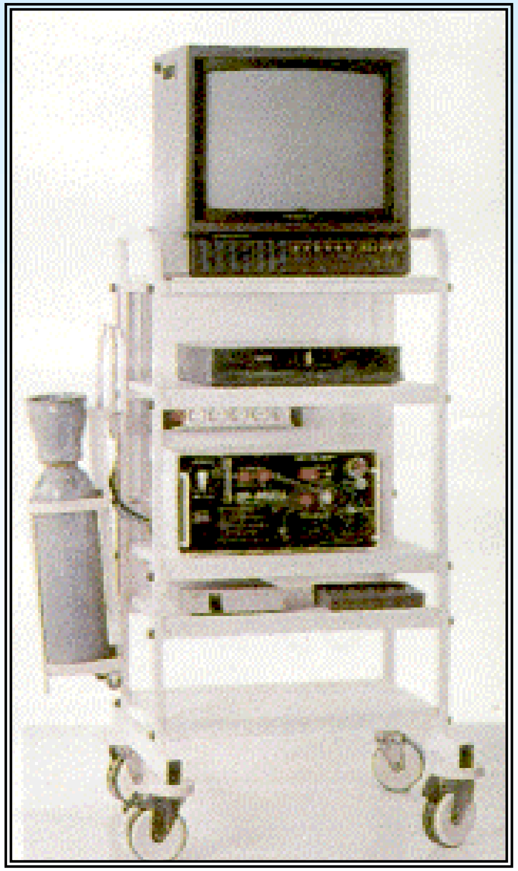


Multivalent Nursing Equipment

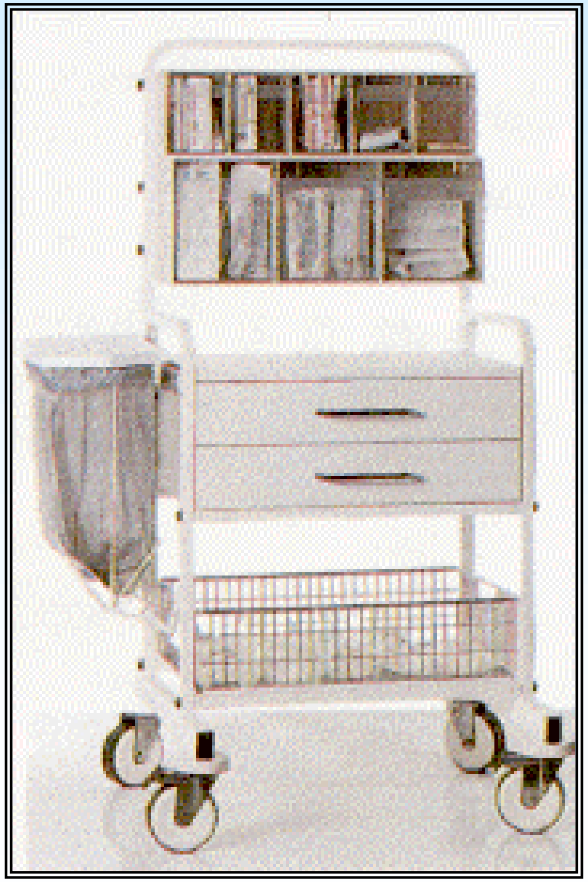


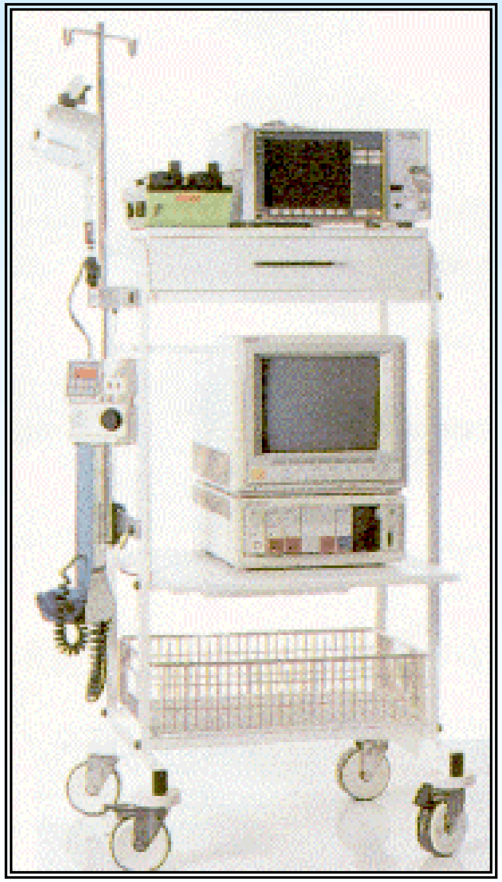


Increased Care Equipment in the Wards



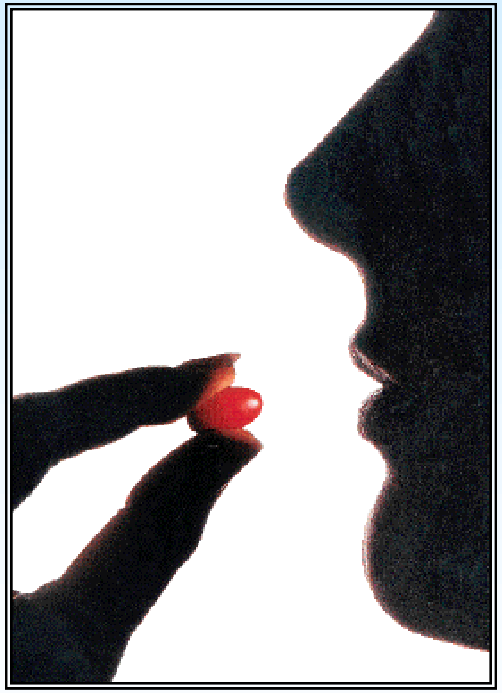
Patient Records and Data Networks in the Wards





The typical content of the Patient Record

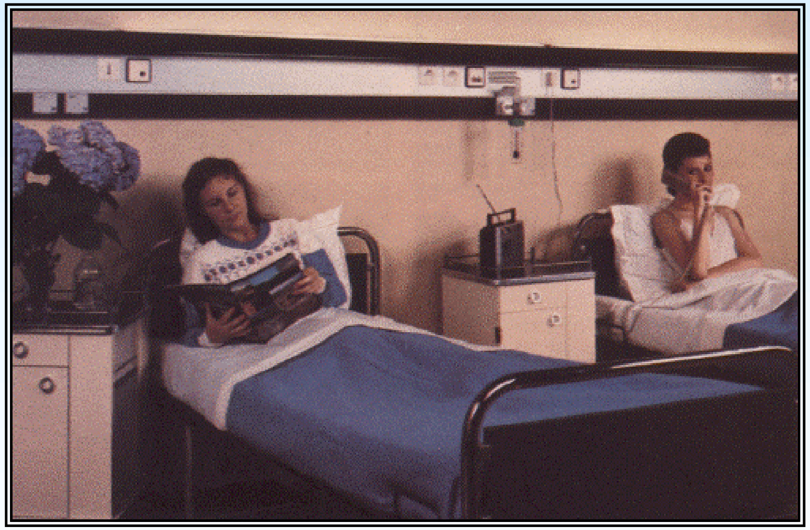
- Patient History.
- Physical examination results.
- In vivo Dignostic Examinations.
- In vitro Laboratory Values.
- Medical Images.
- Pharmaceutical Treatment.
- Nutrition.
- Physiotherapy.
- Surgert and Post-operative care.
- Psychological and Social Care.



Paperless Patient Record?

Training in the Wards

The future of the Hospital Wards



- *Decrease of the Mean Inpatient Stay Period.*
- *Day Wards.*
- *Observation Wards.*
- *Home Care.*
- *Patient Participation in Care Procedures.*
- *New Institutions for the elderly people.*
- *Health tourism.*

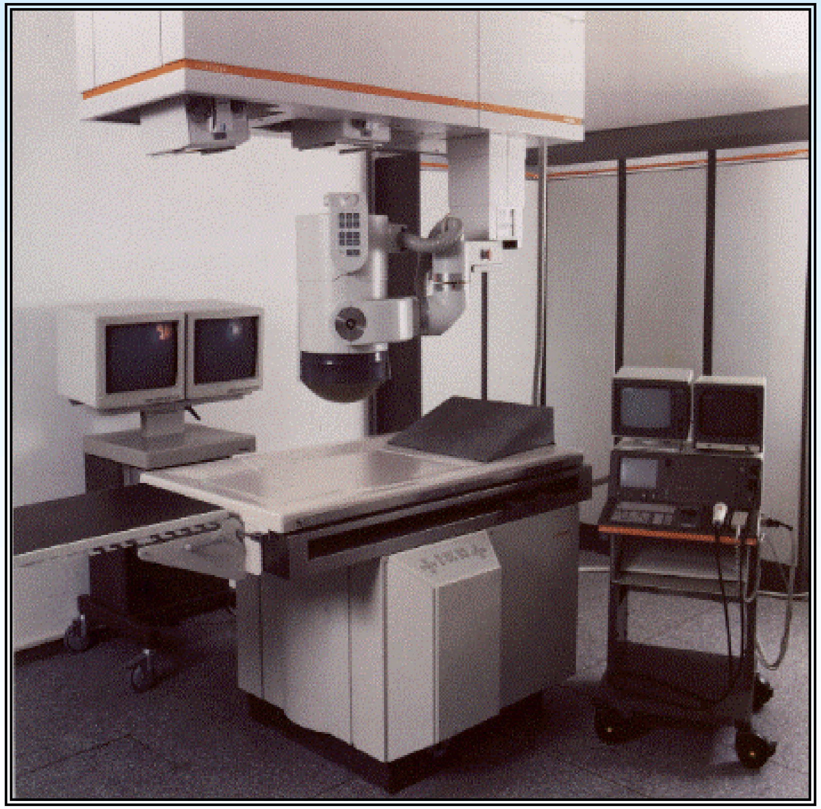
Other Therapeutic Technologies

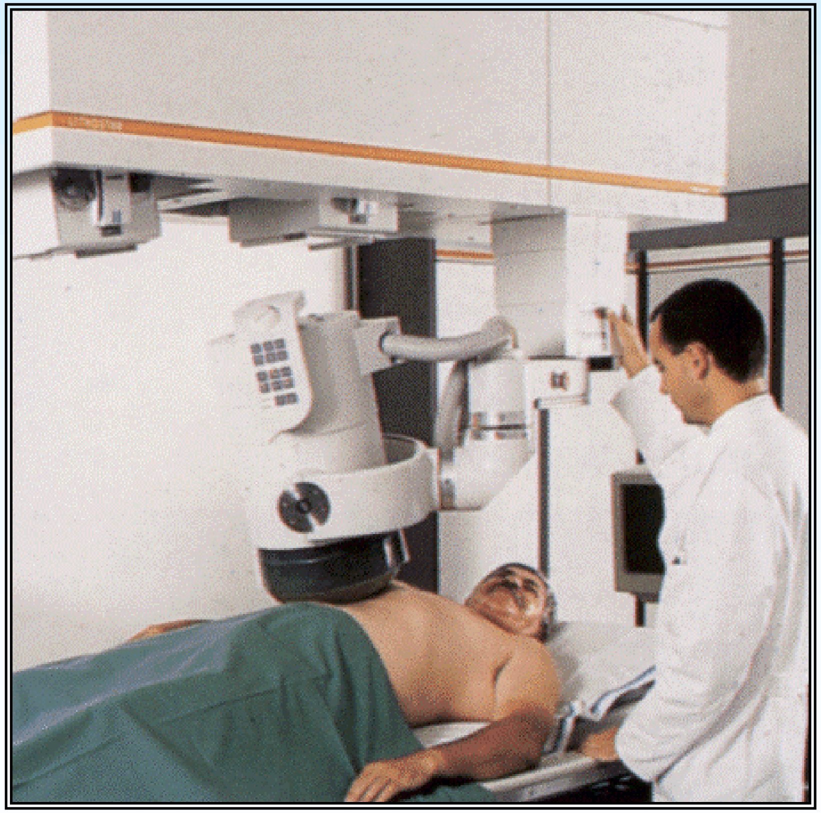
Therapeutic Technologies beyond Surgery

- Ophthalmology LASER.
- Lithotripsy.
- Radiotherapy.
- Hyperthermy.
- Physiotherapy.
- Haemodialysis .
- Hyperbaric Pressure Chamber.

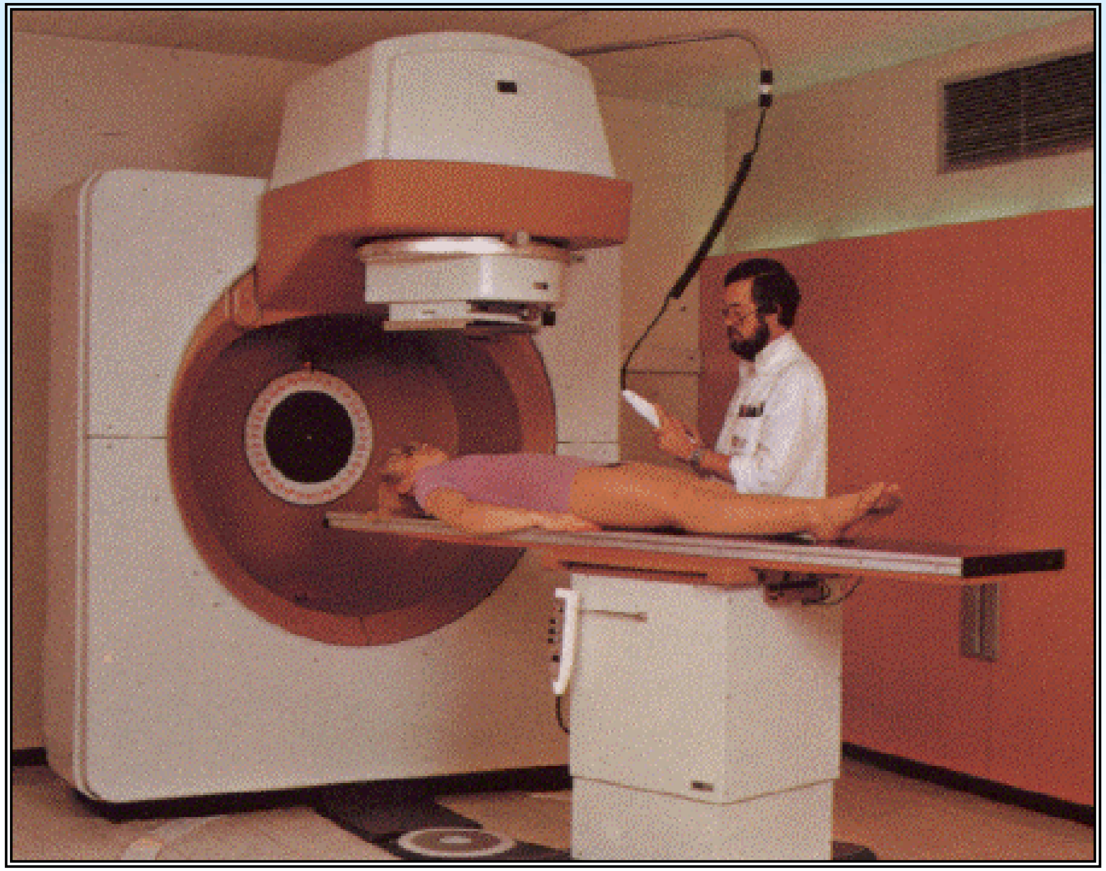
Ophthalmology LASER

Lithotripsy



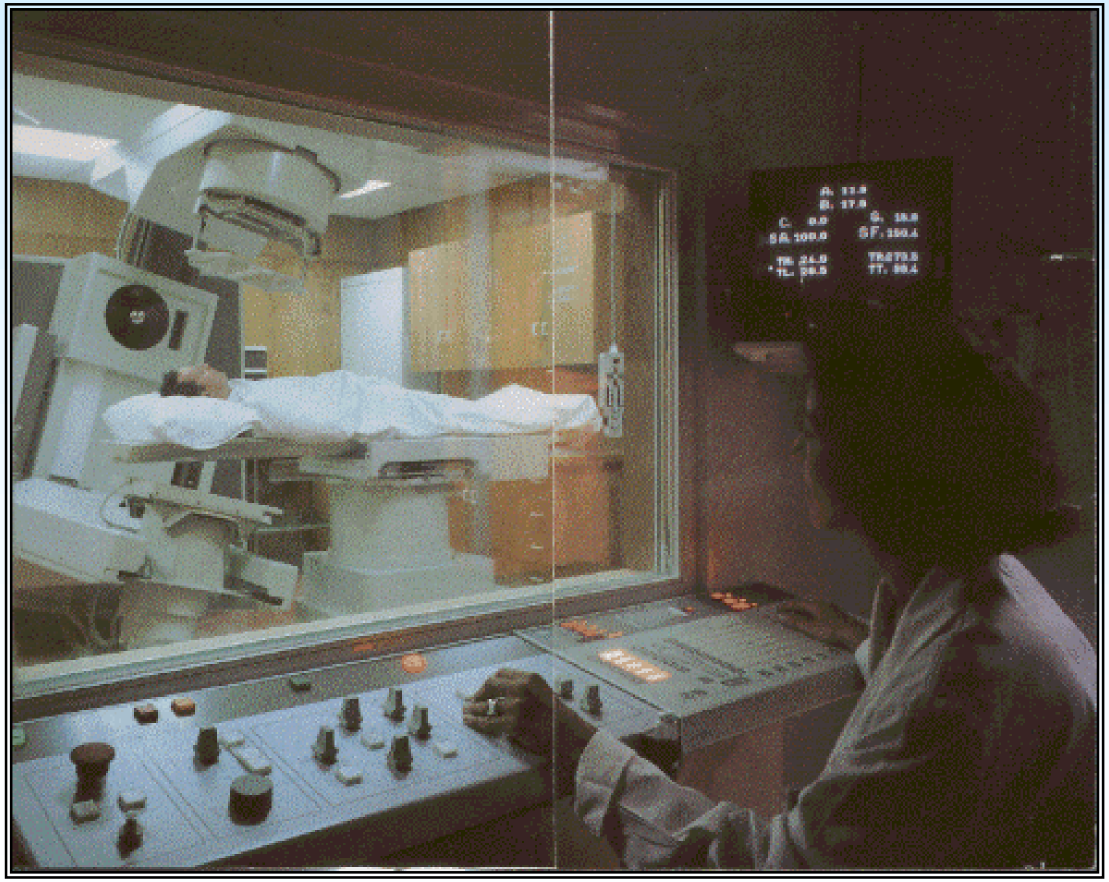


Radiotherapy



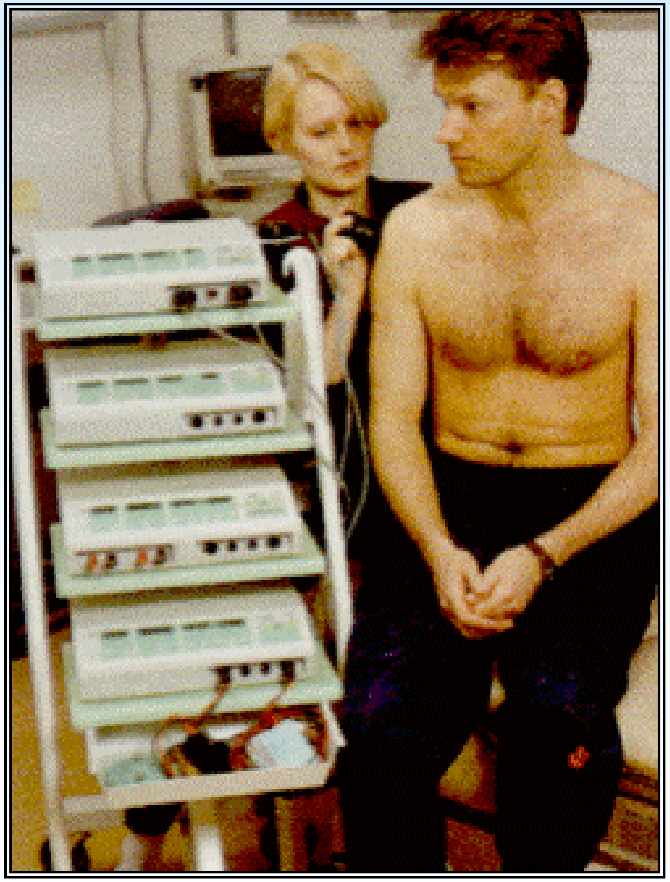
Patient positioning

Simulator - Localizer



Treatment Planning

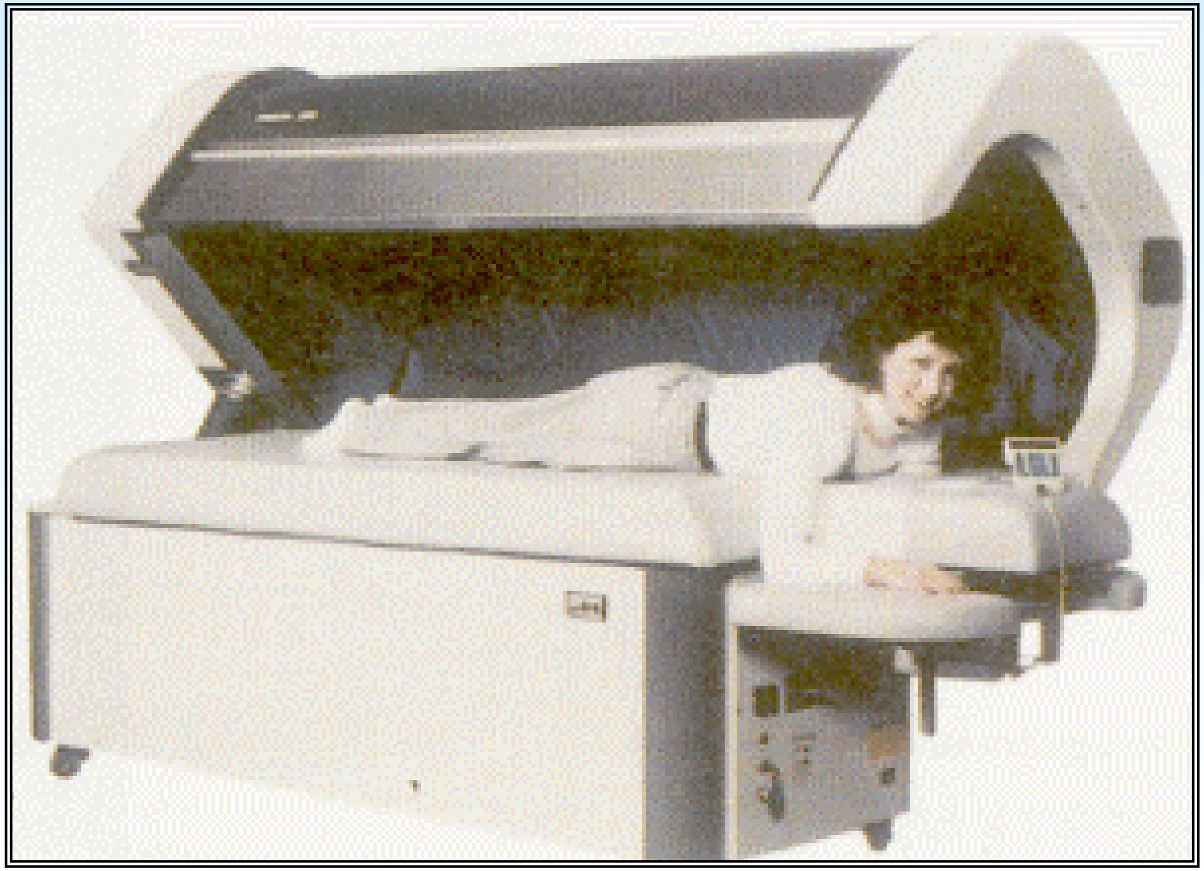
Hyperthermy



Physiotherapy

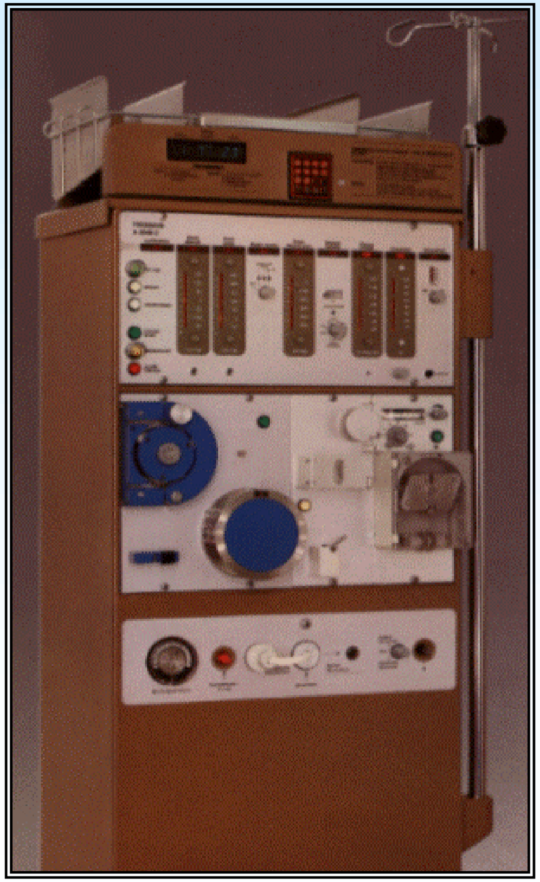
Prosthetics and Rehabilitation

Hyperbaric Pressure Chamber



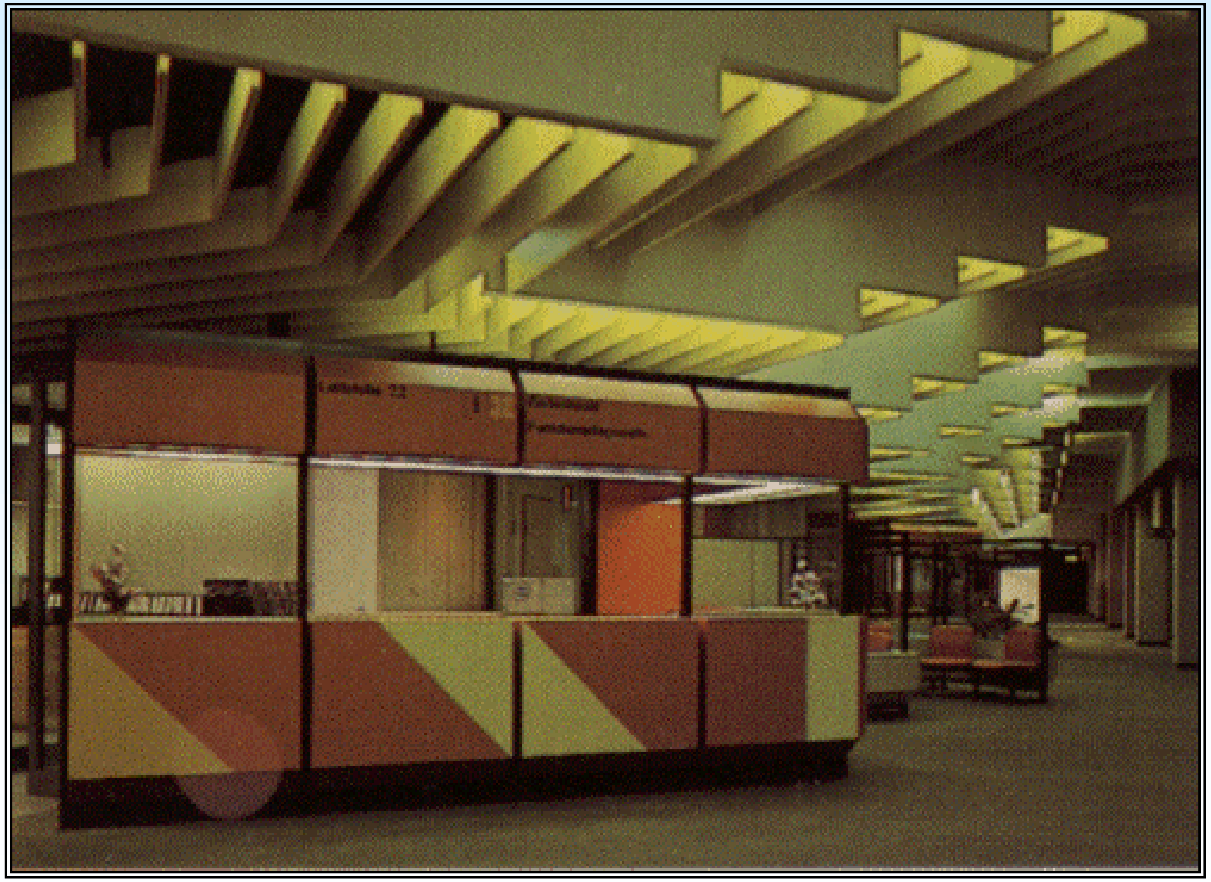
Haemodialysis

Haemodialysis Unit



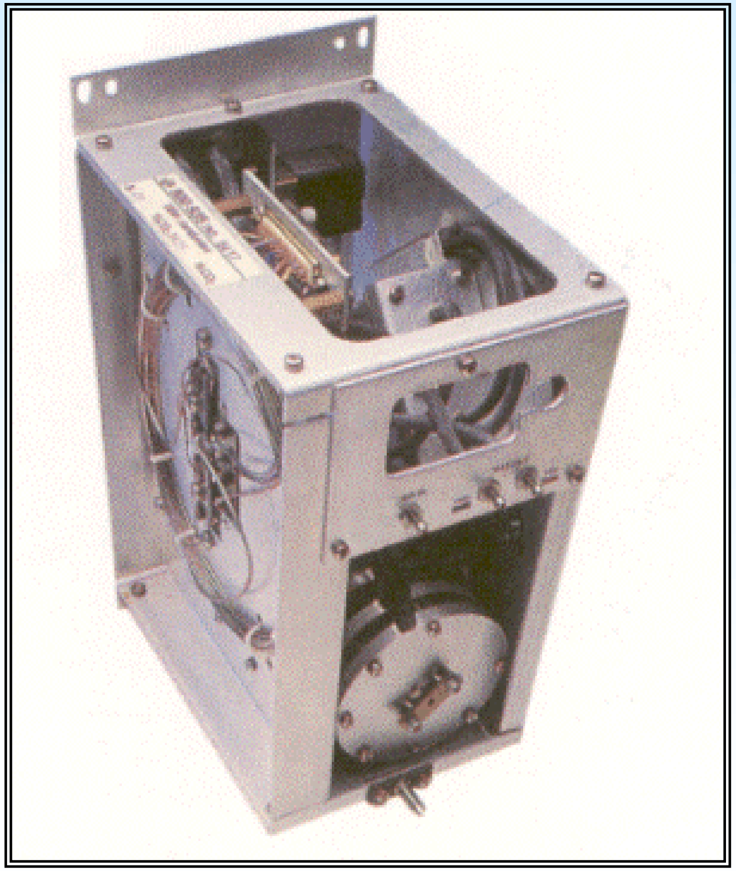
Supporting Facilities in a Modern Hospital

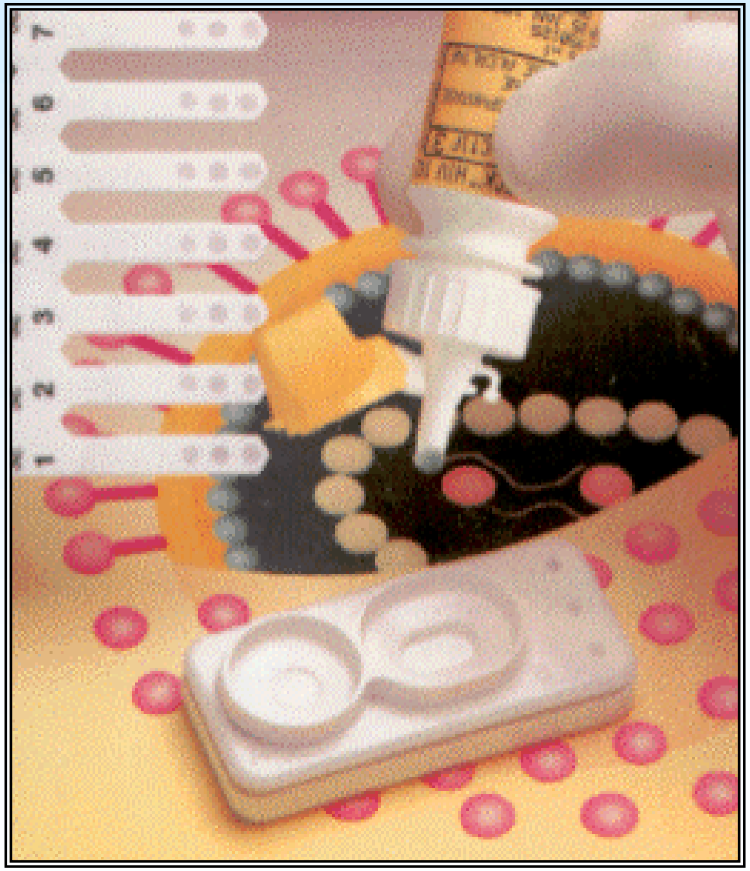
Administration - Public Relations



Service and Maintenance

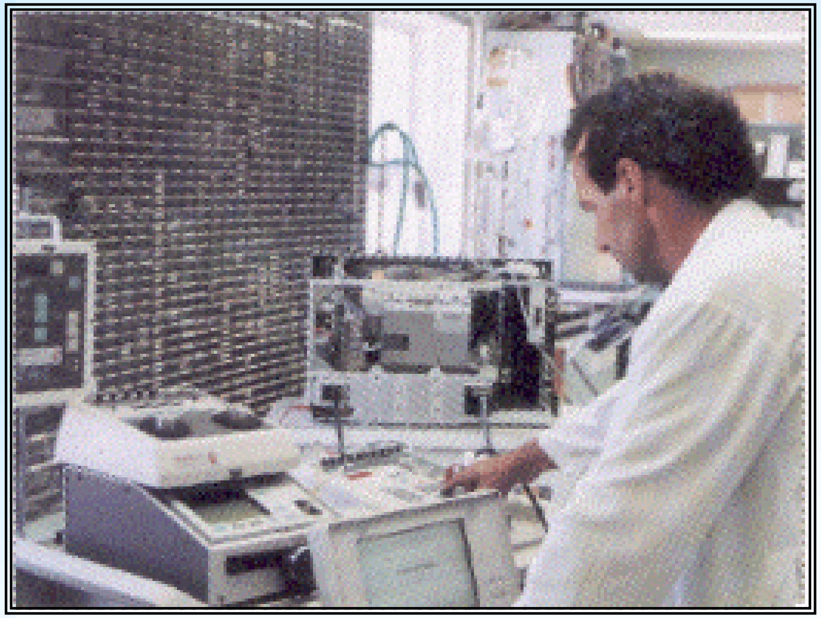
Equipment, Reagent, and Disposable Evaluation and Purchasing

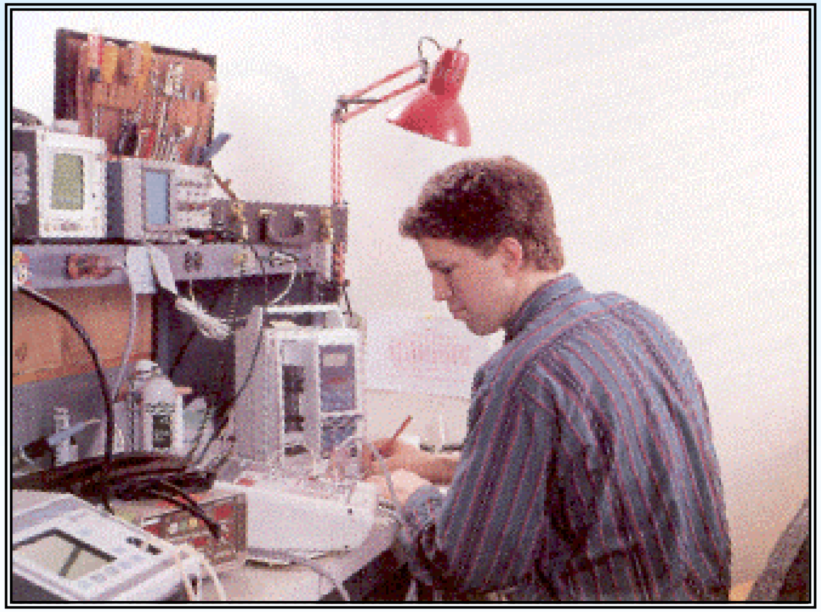




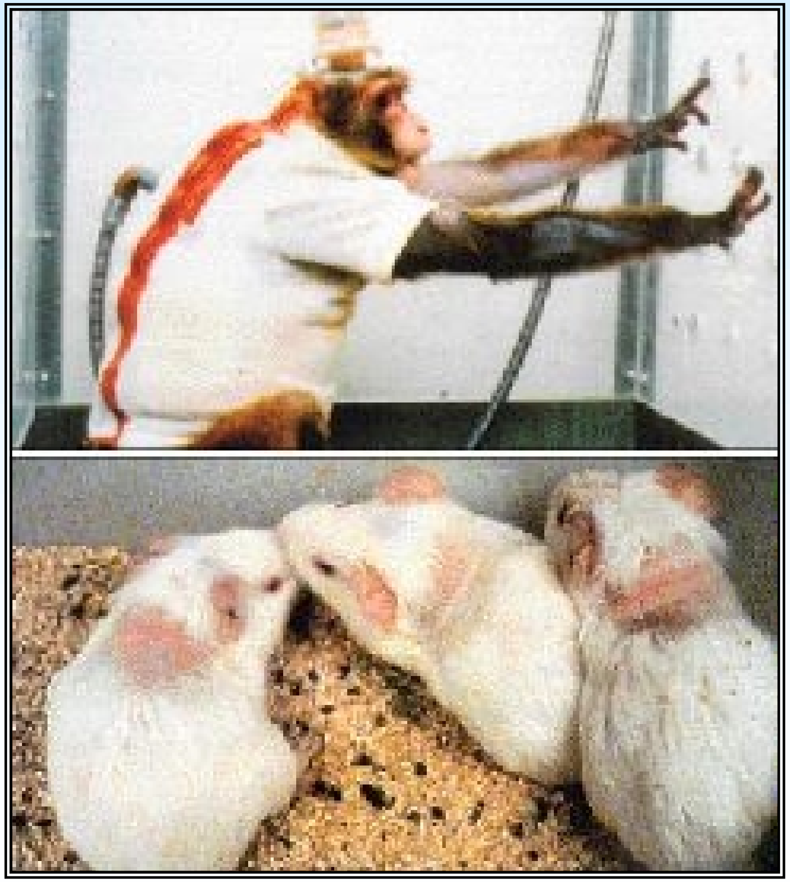
Material Management and Stores

Testing and Calibration of Biomedical Equipment





Supporting Medical Research



Personnel Continuous Education and Evaluation

Working Environment (Restaurant, cultural etc.)