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The trend is clear: more and more hospitals worldwide are building Hybrid ORs. The combination of a conventional OR and large imaging modalities such as angiography systems, CT or MRI has become indispensable in the modern intraoperative diagnostic world. Hybrid procedures such as Cardiac / Vascular interventional work and open heart surgeries have been performed in cath labs for years. However now multi-disciplinary procedures in Neuro, Orthopedics, Trauma and Vascular, can also partake and evolve in the innovative Hybrid OR environment. The Hybrid OR has become the image guided surgery operating room. Pre-operative scanning is becoming an even more vital aspect of discussion and should be used during the interventional work. The combination of CT or MR scans with Angiography can be done preoperative, intraoperative and in postoperative phases. However as new fields open, new discussions in the treatment case of oncology as well as traumatology arise. The integration of interventional and surgical techniques requires a new working environment for an interdisciplinary therapy team: the Hybrid Operating Room. A deep understanding of the clinical applications the current and future technology and their implications on workflow and workplaces is needed for a sound room design.

That's why we have developed this information package devoted to giving healthcare specialists the necessary background related to our experience in building Hybrid theaters.

Many questions arise once the decision has been made to install a Hybrid OR:

- How much planning and installation time will it take to have the new Hybrid OR set up and running?
- Who should manage the project and who should be part of the project team?
- Which industry partner can assure an efficient and smooth implementation of the project?
- Which major disciplines are practiced in a Hybrid OR?
- Which kind of table is needed? An examination table or a surgical table with interchangeable table top?
- Is a Hybrid OR replacing a cath lab in the radiology department?
- Is a laminar flow field really required or could it also be a Hepa Filter system?
- What are the most important elements to make the investment really pay off?
Good questions, since the multifunctional use of the Hybrid OR requires a more sophisticated space design and functional working concept than conventional ORs. Complex planning and technical requirements, due to size and equipment space, should be taken into consideration. Particularly, room dimensions, medical and technical equipment, ventilation, air conditioning systems, electric installations, and radiological protection have to be considered. The main challenge during the planning and building phases of the Hybrid OR is to integrate the numerous different components into one comprehensive functional system.

Every Hybrid OR is a customized solution for each particular hospital in which it is installed: architectural aspects, project planning, application areas, and last but not least, the available budget have to be considered to enable a successful implementation.

This road map summarizes the most relevant hospital planning, industry, and end user aspects involved in the installation and setup of a Hybrid OR, including the room size and dimensions, project organization and management, the different integration phases, and practical implementation examples.
Why a Hybrid OR?
Benefits for the patient and hospital

The rationale for a Hybrid OR is manifold. The interdisciplinary teamwork of interventional medicine and surgery opens new, innovative, and patient friendly therapy options, e.g., minimally invasive heart valve replacement or open-heart surgery without extracorporeal circulation. Particularly, high-risk patients benefit from the Hybrid OR since the diagnostic procedures and the therapy itself take place in one session and the transport to the radiological unit and back to the OR can be avoided.

The timely coordination of the diagnostic procedures and intervention is easier and does not require extra administrative capacity, and last but not least, intraoperative imaging diagnostic procedures are becoming a standard due to the decrease in the number of conventional open surgeries performed and the increase of minimally invasive procedures.

The installation of a Hybrid OR is an expensive endeavor, but it pays off with optimized use of the technical and human resources: Hybrid ORs are particularly cost effective when they are used for multidisciplinary purposes – also as a conventional OR – improving the capacity utilization. The management of high-risk patients is particularly relevant when considering the cost effectiveness of a Hybrid OR.

Hospitals with a Hybrid OR have acknowledged a profit after approximately three years. The angiography system can be adapted for an interdisciplinary use of the Hybrid OR beyond the normal X-ray and fluoroscopy: special software enables CT similar pictures, using navigation tools and mapping (overlay of pictures) functionalities. Combining the Hybrid OR with navigation, CT, MRI, microscopes, and robotics facilitates a broad spectrum of therapeutic options and improves the overall quality of the medical services offered by the institution. The future of Hybrid ORs looks towards image fusion, using CT, MRI and PET for treatment, planning and navigation.

The use of a Hybrid OR offers multiple medical and economic advantages for the patients and the hospital

Patients
- Fast diagnosis and therapy
- Reduced risk
- Patient-friendly
- Care of high-risk patients
- Faster mobilization
- Easier rehabilitation
- Shorter hospital stay
- Minimizing radiation exposure

Hospital
- Enables the teamwork of different specialty areas
- Use of new innovative therapeutic techniques
- Optimization of therapeutic methods
- Expansion of the medical services offered
- Clear positioning in the health (regional) market
- Cost effectiveness due to less OR-slack time
- Cost effectiveness due to multidisciplinary use of the resources
- Cost effectiveness due to interdisciplinary use
- Radiation reduction
- Advanced imaging quality
- Complex cases can be addressed with new devices
Planning the Hybrid OR

The installation of a Hybrid OR requires a coordinated architectural, constructional, and technical plan. Multiple internal and external resources are needed – end users, specialized architects and engineers, hygiene professionals, authorities, and the vendors – are involved in the Hybrid OR project.

The initial situation is seldom an easy one and it should be evaluated early in the process. Project objectives and framework are usually vague or undefined. The necessary budget might not be clear or the assumptions in terms of which hospital units are going to use the Hybrid OR are unspecified. Unclear responsibility areas and undefined clinical demands are additional challenges.

Hybrid operating rooms are extremely complex working environments, where a large team of surgeons, interventionists, nurses, anesthesiologists, perfusionists, and technicians need to work seamlessly together.

The sponsor should always take into account that a tender process based only on the price of each component will most probably lead to a difficult integration of the functional parts provided by different companies. This will result in extra costs due to additional adjustments required and remedial actions. To avoid this, tenders for complex projects such as the installation of a Hybrid OR, should focus on an overall master plan. It is advisable to define the frame and expected deliverables keeping the final integrated product in mind. This tender, defined as a whole, will encourage vendors to propose a comprehensive proven solution.

The hybrid trend is not a suppliers’ trend. Hybrid ORs have enormous potential for surgical facilities where high-quality 3D and 4D imaging is provided in a sterile environment and utilized beyond departmental boundaries.
Planning the Hybrid OR
Project set up

The hospital architect, the hospital planning consultant, and/or an external medical project management team together with the sponsor are responsible for the project set up.

A precise definition of the basic project modules is mandatory at the very beginning of the Hybrid OR project: needs assessment – the basis for the planning –, project objectives, and project organization for the complete project. All relevant aspects of the different applications, needs of the interdisciplinary teams, space classification, workflow, and visualization concepts have to be taken into account. The architect consolidates all the individual plans of the vendors involved in the building of the Hybrid OR along with the companies providing medical and technical equipment in one master plan - thus minimizing the potential risks of incompatibilities between the medical technical equipment and the gas, electrical, and air conditioning systems.

Once the comprehensive preliminary design and blueprints are ready, the planning for the integration of the different acquisition processes should follow, giving special attention to the clear definition of the interfaces between the participating companies. The results are consolidated in a detailed execution plan.

Key decisions and investment considerations

Several key aspects have to be discussed in an early stage of the planning process since they need to be integrated in the overall budget plan.
Planning the Hybrid OR

The building

The planning of a Hybrid OR lasts 12 to 18 months and the execution phase will require another 6 months to a year, depending on whether it is a new building or the building is being remodeled. A Hybrid OR is easier to install in a new building where the space requirements have already been incorporated, whereas in a renovated building, special challenges may be encountered such as insufficient ceiling height, steel beams and columns, or limited air conditioning and the associated space requirements. The separation of the air conditioning and routine OR workflow from the OR section being refurbished is the main challenge when converting a standard OR into a Hybrid OR. In this case, the use of flexible modular wall systems and fixtures that adapt to the local conditions of the existing OR and comply with the OR hygiene standards are the best alternative.

The choice of air conditioning is not trivial, due to its key role in infection prophylaxis and compliance with occupational health standards in the OR. Only a limited amount of technical solutions are available and these should be discussed within a team of hospital hygienist, selected physicians, and the consulting project manager. The classification of the OR rooms in different categories is determined by the characteristics of the different applications: duration of the interventions, size of the surgical fields and the number and arrangement of the instrument tables. An LAF system with the appropriate size and performance is mandatory to acquire the needed certification (e.g. 1a category ORs as European standard), thus posing special demands to the construction planning. The ideal size of the sterile area in a Hybrid OR is 3.2 x 3.9 m or more, mainly determined by the flexible positioning of the OR table and the associated workflow. The most common used table tops have a length of 2700 mm or 2900 mm with a longitudinal shift of 1000 mm. To be on the safe side you have to have additional 20 cm to be covered under LAF/Hepa Filter systems.

The complexity of the Hybrid OR implementation project requires an experienced project and industry partner from the very beginning. Particularly during the planning phase, a detailed three-dimensional representation generated with customized 3D planning software is an invaluable tool that will allow planners and architects to avoid installation issues during the execution phase.

The fitting of the medical and technical equipment is often underestimated: a long OR table, the ceiling mounted angiography system, or a floor anchored C-arm may change the overall space concept. Despite being new or converted building, a Hybrid OR requires more space than a standard OR (i.e. for the OR room itself and the technical control rooms). More medical and technical personnel, as well as the imaging equipment specify a minimal OR space requirement of 80 m², the technical and control rooms require an additional 12 to 14 m² each (see scheme page 10).

The air conditioning system plays a key role in the compliance with hygiene standards. Laminar airflow (LAF) systems or HEPA Filter systems are used to provide a germ reduced air circulation in the surgical field and the sterile areas maintaining a permanent vertical airflow from the ceiling to the floor of the OR.
Technical blueprints or 3D schemes facilitate the planning process from the beginning. The 3D representation of the room itself and the selected equipment are key during the specific project planning phase in order to accurately analyze the positioning of the equipment and avoid collisions. The Hybrid OR can be optimized for the expected workflows.

Specialized project partners, such as Maquet, provide 3D representations and technical blueprints.

Hybrid OR with floor mounted angiography system. The pivoting range of the robot arm is marked on the floor.
Hybrid OR with a ceiling mounted system. Ceiling racks and mounting brackets with multiple widths and lengths are available from different manufacturers.
Planning the Hybrid OR: Possible applications and the related medical equipment

**Equipment:**

1. OR table
2. Imaging system
3. OR lights
4. Ceiling supply unit for anesthesia
5. Ceiling Supply unit for monitors
6. Heart-lung machine
7. Contrast injector
8. Ceiling supply unit for endoscopy/ surgery
9. Preparation table
10. Mayo instrument stand
11. Anesthesia ventilator
12. Laminar air flow
13. Modular wall system

**Rooms:**

A. Image guided operating room
B. Scrub/ washroom
C. Exit
D. Preparation room
E. Storage room
F. Control room
G. Technical room
The Hybrid OR room plan must be determined with a thorough and detailed analysis of the applications and their technical requirements. The room structure and the technical equipment have to be adapted to the workflow in the OR, i.e. if cardiac surgeries and cardiology interventions will take place, then the working conditions imposed by these procedures have to be respected. The placement of the OR table, the angiography system, and the rest of the equipment have to be discussed with the interdisciplinary OR team to make sure that their workflow requirements are met. Key items for the physicians are a direct and unhindered access to the patient and the monitors and displays as well as the synchronization of the imaging systems and the OR table. Clinical application specialists from the industry can reproduce the workflow in detail within the OR during the planning phase. The workflow of all the applications planned, such as general surgery, traumatology, vascular surgery, neurosurgery, etc. have to be considered and the Hybrid OR adjusted to the requirements posed by each discipline. Different table tops have to be planned in order to cater for these applications, this too should be discussed with the relevant OR management team.

Another important factor is the monitoring required by the different applications: the use of the angiographic system as well as any other routine surgery (e.g. endoscopic surgery) without angiography needs to be taken into account. Working in a Hybrid OR demands a high level of cooperation, communication, and an interdisciplinary attitude from the different professional teams. Implementing innovative diagnostic and therapeutic procedures might require a change of the routine workflows. E.g., the surgeon will have to consider repositioning the patient for a 3D image with a static angiography system, since the system is not as flexible as a mobile C-arm. Working with navigation or robotic technology will demand a considerable learning curve from the user.
**CT and MR:** The choice of the imaging system and its integration in the OR are key planning aspects. Orthopedic surgeries and trauma surgeries use a floor mounted CT that can be brought to the patient (sliding gantry) or in some cases can be placed outside the OR.

An MR system is needed for neuro surgery, e.g. in operations on brain tumors. The MR is floor mounted in the OR, or in an adjacent room, resulting in what is called “one room”, “two rooms” or even “three rooms” solutions which can be harmonized with the angiography system. The influence of the strong magnetic fields on the surgical area and the rest of the equipment also have to be considered, requiring the installation of flexible modular wall systems.
Using 3D tool for clarifications

Room design for double sliding CT use
**Angiography system:** The angiography system is used for multidisciplinary applications: it delivers normal X-ray images, fluoroscopy images and, with a special hardware and software combination, it can also generate CT-like images. Additional software enables it to be used for navigation and mapping (fusion with CT or MR images). Hybrid heart interventions require an angiography system that can be either floor or ceiling mounted. Mobile fluoroscopes are not always appropriate for full-fledged interventions. A benefit of the ceiling mounted angiography systems is that they enable flexible imaging of the patient without moving the OR table during the intervention, but these systems have triggered a discussion on the hygiene and approval of 1a class ORs. There is enough experience in the installation of ceiling mounted angiography systems in combination with LAF systems to comply with the required high hygiene standards. For example a ceiling mounted, movable angiography system is able to offer enough space for the installation of a ceiling mounted LAF system. However, ceiling mounted equipment occupies a large area of the ceiling surface, which is also required for the OR lights and other ceiling mounted supply units. As a result, the OR lights cannot be mounted above the OR table but have to be mounted sidewise and brought into the adequate position during the intervention. In the context of ceiling mounted equipment, the main challenge is to define the appropriate ceiling design in order to enable the installation of OR lights, room lighting, ceiling mounted supply units, as well as the air conditioning system.

A new Matrix layout was therefore developed to insure the right positions for OR lights and pendants. Floor mounted monoplane or biplane systems are less flexible due to their radial range, but do not pose hygiene issues and offer a greater range of imaging applications for the different medical areas.

Nevertheless for all systems, the planning has to include a detailed analysis of the static needs, the mounting of the OR lights and ceiling supply units. The manufacturers are key partners in this process and the placement of the different equipment units should be agreed on, with them in order to avoid collisions.
**OR table:** The OR table has to comply with the demands of the surgical and interventional procedures: it should be radiolucent enabling full body imaging and move in such ways, that the patient can be vertically or laterally positioned. Interventional catheter procedures also call for a floating function, enabling rapid and precise movements during the procedure. In the Hybrid OR, multifunctional OR tables that combine these possibilities are strongly recommended. These have flexible carbon fiber table tops that can be used for the different applications. The Hybrid OR can be used as a normal OR when a universal OR table top is installed and customary universal OR table tops can be configured with carbon fiber elements to enable angiographies. In this case, it is a key condition that the angiography system and the table are integrated into a synchronized working unit.

Today’s hybrid tables should be flexible. Being able to change the table top can allow for multiple surgical disciplines to be carried out. As patient positioning is a high requirement of today, most installations have been equipped with two or three different variations of table configurations which, for example, allows a beach chair position. Hospitals also refer to this as “segmented table tops”.

**Digital OR integration:** Modern OR documentation and quality control processes in multifunctional environments pose multiple demands to the Hybrid OR. An easy and efficient management of all images, patient data, room control, and image and video transmission is best implemented into a central control station. Special attention should be given to account for the requirements of the different devices e.g. ultrasound, X-ray equipment, endoscope, etc., while enabling an independent use of the systems. Due to the multifunctional use, 6 to 8 monitors with 8-12 input signals are typically needed in the Hybrid OR. The images and the associated information are displayed in two black & white screens. Additional information is displayed in up to 6 color screens (≥ 24") that can also display a copy of the X-ray image. The compatibility of the different software with the existing IT infrastructure (e.g. HIS) should be guaranteed and a built-in wall workstation connected to the HIS should be foreseen.
Planning the Hybrid OR
What comes first

The integration of each component in the frame of the complete concept is key for a successful installation. Each and every interface and work process has to be exactly defined. If the clinical application as such, is not considered and the integration is based only on the medical equipment, problems can arise during the use of the OR in combination with the new imaging system. The equipment may clash if OR table extensions are not appropriately planned or the cable connections have not been foreseen. The main reference points are the OR table and the imaging system and these should be defined first. A 3D software tool to display the different planning phases in scales is a valuable support tool during the planning phase.

The following integration steps have proven suitable in practice:

1. Modular wall system with X-ray protection
   (2 mm Pb - up to room height of 3000 mm) including control panel
2. Allocation of the technical and control rooms
3. Integration of the imaging system – floor or ceiling mounted. Eventually combined with the OR table system
4. Universal OR table with carbon fiber modules or a flat carbon fiber table top for different applications including accessories (floating system)
5. Integration of the air conditioning systems (LAF system) – might include the appropriate room lights
6. Definition of the sterile area: OR field plus instrument stands, etc.

7. Fitting of the OR lights and the ceiling supply units
8. Connection to the IT network and internal communication system
9. Information, documentation and monitoring displays (digital integration)
10. Ultrasound, heart-lung machine, injector, robotic, and microscope integration
11. Integration of the imaging system steering unit and the corresponding hardware
12. Mounting of the cabinet system for accessories
Implementation example

Valley Private Hospital Melbourne, Australia

The Valley Private Hospital is an acute medical and surgical hospital southeast of Melbourne, Australia. The OR which was originally equipped for cardiovascular interventions is also being used for neurosurgery. The OR was refurbished to a Hybrid OR and opened in September 2012 after 7 months of planning and building time. The fast implementation was the result of an intensive collaboration, detailed preparation, and fast decision making processes agreed between the sponsor and the two industry partners in charge of the remodeling – Maquet and Siemens Healthcare.

More than 30 professionals were involved in the process: CEO, architects, end users, and technicians. Due to static conditions (iron beam ceiling) and the performance package offered by Siemens and Maquet, a floor mounted Artis zeego® angiography system from Siemens were chosen together with a MAGNUS OR table system from Maquet. All other modules needed for the custom tailored OR integration – modular wall system VARIOP, the MAGNUS OR table with diverse table tops, ceiling mounted supply units, OR lights, and digital OR integration – were provided by Maquet.
Implementation example
Maquet Academy Rastatt, Germany

Two complete Hybrid ORs convey to physicians, perfusionists, nurses, technicians, hospital managers, and hospital planners an overall impression of the most relevant aspects for the planning, implementation, and equipment of the Hybrid OR. All X-ray functionalities can be simulated with a ceiling mounted angiography system (Allura FD 20, Philips) or a floor mounted solution (Artis zeego®, Siemens Healthcare). The movement sequences and the different positioning of the C-arm can be demonstrated live. The Hybrid OR equipment e.g. table system can be configured and all relevant workflows can be simulated. Those interested in Hybrid ORs can experience a realistic and practical demonstration of all possibilities available for their hospitals. Maquet has gained and offers a significant amount of experience in the implementation of different Hybrid OR configurations with over 600 Hybrid ORs planned and installed together with Siemens, Phillips, Toshiba, and GE.

OR lights with a special Hybrid OR configuration. Ceiling mounted angiography system and OR table with a universal table top.

Interchangeable table tops allow for seamless transition between surgical procedures.
Maquet Hybrid OR Portfolio

**Modular wall system (VARIOP):** The modular wall system adapts to all room conditions and fits into new, expanded, or remodeled rooms – short building time, excellent flexibility, and investment security. VARIOP meets all fire, radiation and sound insulation construction standards.

**OR table system MAGNUS 1180:** Unique X-ray alternatives and extreme angles for a perfect and ergonomic approach provide optimal support for the patient and the OR team. The OR table can be equipped with one piece carbon fiber table top (2200 mm to 3000 mm length) or a universal table top with adaptable modules and carbon fiber elements for the individual patient positioning.

**Digital integration and monitor concept (TEGRIS):** Digital OR integration with TEGRIS enables an easy management of various image sources, e. g. endoscope, C-arm, microscope, image intensifier, OR light camera, PC, or anesthetic data, no matter which images are required for a specific surgical procedure.

**OR lights PowerLED / HLED:** The LED systems set standards in light quality, safety, comfort, and functional efficiency within a sustainable environmental development. Special configuration capabilities for the Hybrid OR enable an optimal use of the OR lights together with the imaging system.

**Ceiling mounted anesthesia / surgery / endoscopy, and multimedia supply units:** The high functionality and flexibility of the ceiling supply units simplify work processes in the OR.

**Heart-lung machine:** The CARDIOHELP system is a user-friendly platform for powering various extracorporeal circulatory, and respiratory support applications.

**Anesthesia (FLOW-i):** FLOW-i combines modern ventilation performance and anesthesia administration in a patient-friendly device. FLOW-i is modular and ergonomic as it can be adapted to different environments and updated as required.

**Suction and tapping systems (MEDAP):** Electrical suction pumps for surgery, critical care, and homecare, as well as central gas supply systems.

**Imaging system (Angiography system / MRI / CT):** Maquet develops complete Hybrid ORs in close collaboration with the world leading manufacturers of imaging systems: GE, Phillips, Siemens, and Toshiba.
Summary

**Hybrid ORs are being used** for different diagnostic and therapeutic interventions. Angiography system, CT, and MRI can be used separately or in combination in the image guided surgery operating room.

The biggest challenges in the implementation of a Hybrid OR are the demanding technical and planning conditions and the coordination and integration of the different equipment provided by different vendors into a functioning overall concept. Thorough preparation and expert planning are key for a successful implementation of the project, including needs assessment, definition of the project objectives and organization, meticulous preparation of the tendering process, and defining the vendors, who play a major role in the implementation of the project. The industry partners should have enough experience and expertise in their specific areas and on how their systems fit within a Hybrid OR concept and should be consulted early in the planning process. A central project management and cooperation with a minimum number of vendors streamline the technical and project decision making process, optimizing the efficiency of the available resources.

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