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Hybrid Operating Room Suites

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Key Messages

- This Horizon Scan summarizes information related to hybrid operating room suites for surgical procedures beyond thoracic surgery, neurosurgery, and emergency vascular surgery, including a list of some of the hybrid operating rooms in Canada, a description of some related published studies, and a summary of some important considerations, such as patient and provider experiences and facility planning.
- Hybrid operating rooms combine medical imaging and conventional surgical suites into 1 treatment space and can be used for both minimally invasive and open surgical procedures. They allow surgeons to perform imaging, biopsy, diagnosis, and surgery all in the same room and remove the need to move a patient between an imaging suite and an operating room.
- Evidence suggests that the use of hybrid operating rooms can result in improved patient outcomes and decreased procedure times. Radiation safety for both providers and patients is an important consideration when implementing the use of hybrid operating rooms.
- The use of hybrid operating rooms is well established for thoracic surgery, neurosurgery, and emergency vascular surgery; and is emerging for surgeries such as gynecological, urological, and orthopedic.

Purpose

The purpose of this Horizon Scan is to present health care stakeholders in Canada with an overview of published studies and other information related to the use of hybrid operating room (OR) suites for a variety of surgical procedures to make them aware of the potential benefits, harms, and logistical considerations associated with these suites. Clinical evidence, safety information, cost information, patient and health care providers perspectives, and some operational considerations will be described. This report may be of interest to decision-makers who are building new hospitals, adding new surgical suites, or retrofitting existing surgical suites to become hybrid spaces.

This report is not a systematic review and does not involve critical appraisal or include a detailed summary of study findings. It is not intended to provide recommendations for or against the use of the technology.

Methods

Literature Search Strategy

An information specialist conducted a literature search on key resources including MEDLINE, Embase, the Cochrane Database of Systematic Reviews, the International HTA Database, and the websites of Canadian and major international health technology agencies, as well as a focused internet search. The search approach was customized to retrieve a limited set of results, balancing comprehensiveness with relevancy. The search strategy comprised both controlled vocabulary, such as the National Library of Medicine's MeSH

(Medical Subject Headings), and keywords. Search concepts were developed based on the elements of the research questions and selection criteria. The main search concepts were operating rooms and hybrid. The search was completed on March 9, 2023, and limited to English-language documents published since January 1, 2018.

Study Selection

One author screened the literature search results and reviewed the full text of all potentially relevant studies. Studies were considered for inclusion if the intervention was related to the use of hybrid OR suites for surgical procedures. Conference abstracts and grey literature were included when they provided additional information to that available in the published studies.

Two CADTH Rapid Review reports, [Thoracic Surgery and Neurosurgery in the Hybrid Operating Room](#)¹ and [Emergency Vascular Surgery in the Hybrid Operating Room](#),² were completed before this report was written, and provide an overview summary of the abstracts available for the publications included in the reports. Studies included in the main body of these reports have been excluded from this report and information relevant specifically to the indications addressed by those reviews can be accessed in those reports. The intention of this report is to provide information that was not covered in the previous CADTH works related to indications and uses beyond thoracic surgery, neurosurgery, and emergency vascular surgery performed in hybrid ORs.

Peer Review

A draft version of this report was reviewed by 1 clinical expert with experience operating in hybrid ORs, interventional cardiology, and health technology assessment.

Background

Hybrid ORs are suites that combine imaging equipment like fluoroscopy C-arms (a type of portable X-ray), CT scanners, MRI, and conventional operating equipment to produce a hybrid environment where surgeons can perform both minimally invasive image-guided procedures and open surgical procedures without having to move the patient between specialized spaces.³ Hybrid ORs are used most often used for cardiac and vascular surgeries (e.g., transcatheter aortic valve replacement, endovascular aneurysm repair [EVAR], and stent graft placement). They can also be used for trauma, orthopedic and gynecological surgeries, and other uses.³ Hybrid ORs can be particularly useful when treating a patient whose condition would have previously required multiple single procedures that can now be done simultaneously in the hybrid space. Surgical workflow can be improved by the consolidation of people and equipment into a single space. Hybrid ORs came into use in the 2010s but have become more popular as technology has advanced and minimally invasive procedures have become more common.³ The expense of the construction and maintenance of these surgical spaces means they are often limited to larger hospitals and urban centres and are often funded through hospital foundations.⁴⁻⁹

What Are Hybrid ORs?

A hybrid OR has been defined by the Strasbourg International Consensus Study as a:

[f]acility equipped with full surgical capabilities, including medical imaging based on coordinate systems (CT, MR, cone-beam CT) associated with other techniques (ultrasound, fluoroscopy) and/or guidance systems. Through different types of human-machine interfaces, the planning, guidance, and control stages can be performed intraoperatively in a dynamic fashion (p. 6)¹⁰

Hybrid ORs allow surgeons to do imaging, biopsy, diagnosis, and surgery all in the same room and remove the need to move a patient between an imaging suite and an OR.¹¹ Hybrid ORs are usually based around the integration of imaging equipment into the OR.¹² This imaging equipment may include CT, MRI, C-arm fluoroscopy, or others.¹² Because this high resolution real-time imaging is able to be done during a surgical procedure, surgeons can work with the most up-to-date imaging data that is immediately available to because of the connected devices within the OR.¹² These ORs are built to serve as multipurpose rooms and are most often used for minimally invasive and vascular surgeries, but may be shared by multiple surgical disciplines.¹²

Using hybrid OR set-ups allows some procedures, such as abdominal aortic aneurysm repair, that would have typically required open surgery to be done as minimally invasive procedures instead, thereby reducing the recovery time required for the patient.¹³ Patients who require both open and laparoscopic procedures can have both done in the same surgical visit in a hybrid OR, reducing their need for return visits and multiple doses of anesthesia.³ Additionally, minimally invasive procedures that result in an emergency can be converted to an open procedure in the hybrid OR, reducing the time to urgent treatment and reducing patient transport requirements.¹³

Availability

Hybrid ORs are currently in place in most Canadian provinces. [Table 1](#) provides a nonexhaustive list of these ORs based on information available online via press releases and hospital websites. This list includes the types of procedures and surgeries currently conducted in hybrid ORs in Canada.

Cost

The cost of new construction building and furnishing of a hybrid OR has wide estimates in the literature, falling between US\$1.5 million and US\$3.6 million.¹⁷ Specific cost information was not identified for the conversion of a conventional OR to a hybrid OR suite; however, the costs of converting existing OR space into a hybrid suite can be considerably higher than building and furnishing a new suite.

Table 1: Examples of Existing Hybrid Operating Suites in Canada

| Location, hospital, opening date | Current reported uses |
|---|--|
| Winnipeg, MB ⁴ St. Boniface Hospital Opened December 2022 | Cardiac surgery, vascular surgery |
| Halifax, NS ⁵ Queen Elizabeth II Health Sciences Centre Opened October 2022 | Cardiac surgery, vascular surgery |
| Toronto, ON ⁶ Sunnybrook Hospital January 2022 | Cardiac surgery, vascular surgery |
| Kingston, ON ¹⁴ Kingston Health Sciences Centre Opened November 2021 | Vascular surgery |
| London, ON ⁷ London Health Sciences Centre Opened March 2020 | Cardiovascular surgery |
| Edmonton, AB ¹⁵ Grey Nuns Community Hospital Opened September 2018 | Primarily vascular surgery, with capacity for gynecology and orthopedic surgeries using the same equipment |
| Vancouver, BC ⁸ Vancouver General Hospital Opened November 2016 | Vascular and endovascular procedures, trauma surgeries |
| Calgary, AB ⁹ Foothills Medical Centre (2 hybrid ORs) Peter Lougheed Centre First opened approximately 2013 | Foothills Medical Centre <ul style="list-style-type: none"> • Cardiac procedures • Interventional trauma operating room Peter Lougheed Centre <ul style="list-style-type: none"> • Vascular surgery |
| Montreal, QC ¹⁶ Institut de Cardiologie de Montréal Opening date unknown | Cardiac surgery |

AB = Alberta; BC = British Columbia; MB = Manitoba; NS = Nova Scotia; ON = Ontario; OR = operating room.

Who Might Benefit?

Hybrid ORs may be a benefit to any patient who requires a procedure that involves both imaging and intervention. The addition of the imaging equipment into the room where the procedure takes place reduces the need to move patients between imaging and surgical suites. This could be particularly beneficial for minimizing time to treatment, such as in cases where the patient has a surgical emergency or when the hybrid ORs are used for trauma surgeries.¹⁷ Additionally, these ORs are designed to allow surgeons to convert a minimally invasive procedure into an open surgical procedure without repositioning or moving the patient

between rooms should the need arise. The volume of procedures undertaken in Canadian hybrid OR suites was not identified in the literature. As an example of 1 of the more common procedures done in a hybrid environment, the rate of elective abdominal aortic aneurysm repair in Ontario was 2.2 per 100,000 population in 2016.¹⁸ Between 2010 and 2016 there were 7,257 elective EVAR procedures done in Ontario for people older than 39 years.

Current Practice

Only 1 evidence-based guideline was identified in the literature search results for this report that specified the use of a hybrid OR. The 2019 Canadian Cardiovascular Society position statement¹⁹ for transcatheter aortic valve implantation recommends that transcatheter aortic valve implantation programs should have access to a cardiac catheterization lab or hybrid OR (strong recommendation; medium-quality evidence) and be performed by an interventional cardiologist or cardiac surgeon.

Currently, most hospitals have separate spaces for diagnostic imaging, surgery, and angiography.⁹ This means that when a patient who has traumatic injuries arrives at the hospital, surgeons need to make a choice about which of the many necessary procedures to prioritize within a short period of time. Patients often require multiple surgeries to treat their traumatic injuries in different ways. The hybrid OR space allows both traditional open procedures, like liver repair, to happen at the same time as minimally invasive image-guided cardiac surgery.⁹

Summary of the Evidence

Two CADTH Rapid Review reports, *Thoracic Surgery and Neurosurgery in the Hybrid Operating Room*¹ and *Emergency Vascular Surgery in the Hybrid Operating Room*,² were completed before the writing of this report. Studies included in the main body of these reports have been excluded from this bulletin because they were summarized previously. The report on emergency vascular surgery did not identify any prospective comparative studies of clinical effectiveness for inclusion in the main report.² In the report on thoracic and neurosurgery in the hybrid OR, 6 nonrandomized studies were identified regarding the clinical effectiveness of thoracic surgery for patients with pulmonary nodules and 3 nonrandomized studies were identified regarding the effectiveness of neurosurgery for brain arteriovenous malformations and traumatic brain injury.¹ Neurosurgery in a hybrid OR was found to be an effective setting for the removal of high-grade brain arteriovenous malformations.¹ A lower mortality rate, higher radiological cure rate, and higher rate of good outcomes compared to traditional surgery were observed for patients with brain arteriovenous malformations. For the treatment of severe traumatic brain injuries, the hybrid room within the emergency department was associated with a significant reduction in unfavourable outcomes and time to CT exam and operation compared to conventional treatment.¹ Further details regarding the included studies can be found within these CADTH reports.

For the current report, 2 systematic reviews^{17,20} and 2 systematic scoping reviews^{21,22} were identified from the literature search that assessed the use of hybrid ORs for a variety of surgical procedures. The authors

of the most recently completed systematic review found that a benefit of hybrid ORs was that they could result in decreases in surgical duration and increases in surgical success rates as compared to procedures done in conventional ORs;²⁰ however, in some cases identified in a scoping review, there was an associated elongation in procedure duration due to the complex patient positioning required.²¹ A reduction in mortality and complication rates was also observed.²⁰ The ability to assess surgical outcomes with imaging in the hybrid OR before completing the procedure resulted in fewer reinterventions.²¹ The authors of a scoping review of anesthetic care in hybrid ORs found that common anesthetic-related safety issues included lower equipment reliability, inaccessibility of the patient and airway, and relative isolation of the hybrid OR suite in relation to other anesthesia care areas of the hospital.²²

Additional clinical publications were identified that assessed the use of a hybrid ORs for the following surgical procedures:

- abdominopelvic trauma requiring surgery and interventional radiology procedures (1 study)²³
- localization of small peripheral pulmonary nodules for surgical resection (1 study)²⁴
- temporary transcatheter balloon occlusion of bilateral internal iliac arteries during Cesarean section in a hybrid OR for placenta previa with a high risk of massive hemorrhage (1 study)²⁵
- nonconservative management of placenta accreta spectrum (1 study)²⁶
- interventional treatment for portal vein complications after liver transplant (1 study)²⁷
- pelvic^{28,29} and acetabular²⁹ fracture surgery (2 and 1 study, respectively)
- impacts and outcomes related to the availability of a dedicated hybrid OR for patients with traumatic injury (3 studies).³⁰⁻³²

These individual publications were not summarized due to the volume of literature included in the identified systematic reviews.

Safety

Radiation safety is the primary safety consideration related to hybrid ORs and was assessed in 5 nonrandomized studies and 1 comprehensive literature review; the results are summarized in [Table 3](#) in [Appendix 1](#).

Surgeons' radiation exposure during endovascular surgery in a hybrid OR is associated with both direct and stochastic radiation effects, including an increased risk of malignancy and risk of developing cataracts when compared with surgeons working in a standard OR.³³ Aprons and gowns are typically worn by the surgical team to protect the body from exposure and eyes may be protected using protective glasses with lead-containing lenses.³³

Researchers found that patients undergoing EVAR in a hybrid OR received significantly lower doses of radiation during surgery than patients in a standard OR with portable fluoroscopy.³⁴ They also found that patients treated in the hybrid OR required significantly less contrast media for their procedures and fluoroscopy times were significantly shorter.³⁴

Fidalgo Domingos and colleagues (2018)³⁵ measured values of absorbed radiation before the installation of a hybrid OR, after installation but before administration of a radioprotection seminar, and after administration of a radioprotection seminar. The highest average amount of absorbed radiation was observed in the hybrid OR before the radioprotection seminar was administered. The average radiation exposure for patients was significantly lower in the hybrid OR after the seminar.³⁵

After the implementation of a radiation dose protection program in a hybrid OR, researchers found the mean unprotected eye lens dose measured outside of the operator's lead glasses was reduced by between 55% and 79% for EVAR procedures.³⁶ The average interoperative radiation exposure for surgeons and assistants was significantly reduced when a protection sheet (a sterile, disposable drape that does not contain lead) was placed over the pelvis after surgical exposure of the femoral artery.³⁷ The protection sheet is meant to protect the operator from the surgery's scatter radiation.

Cerna and colleagues (2021)³⁸ assessed the estimated fetal radiation dose and associated risk of radiation-induced carcinoma in childhood for pregnant people with irregular placenta undergoing prophylactic internal iliac arterial occlusion in a hybrid OR. They found that the mean estimated radiation dose to the fetus was 1.49 mGy, which resulted in a 0.02% mean risk of radiation-induced cancer in childhood.³⁸

Cost-Effectiveness

Patel and colleagues (2022)³⁹ conducted a bottom-up cost analysis of hybrid and conventional ORs based on data from 5 hospitals in Denmark. The analysis included costs related to construction, supply and medical device inventory, personnel, and general overhead. In this case, hybrid ORs were defined as an OR in which a piece of imaging equipment was installed. The researchers then calculated the cost per minute for both types of OR using utilization data. The cost per minute for the hybrid OR was 210% the cost of the conventional OR. The cost per minute for the hybrid OR (€9.45 with a range of €8.60 to €10.23 for conventional; €19.88 with a range of €16.10 to €23.07 for hybrid). Costs were calculated based on each minute the OR was in use and did not provide any calculations of the cost of use per patient treated in the space. The costs of the hybrid OR were mostly driven by the related construction costs of the larger footprint required for a hybrid space, total supply and device inventory, and utilization rates. Hybrid OR construction also requires materials not needed for conventional ORs, such as lead lining in the walls and ceilings to manage the radiation produced by the imaging equipment. The fixed fluoroscopy C-arm was the main driver of inventory costs. A hybrid OR used at 50% cost €4.96 more per minute than when it was used at 100%.³⁹

Kinoshita and colleagues (2021)⁴⁰ evaluated the cost-effectiveness of a hybrid room within the emergency department system for patients with severe trauma without severe traumatic brain injury. Cost-effectiveness was assessed using a cost-utility analysis from the third-party payer perspective in Japan.⁴⁰ The hybrid room within the emergency department included an angiography-CT in a trauma resuscitation room. The use of the hybrid room within the emergency department resulted in an incremental cost-effectiveness ratio of US\$32,522 per quality-adjusted life-year gained.⁴⁰ The incremental cost-effectiveness ratio was below the willingness-to-pay threshold of US\$47,619 per quality-adjusted life-year gained when the odds ratio of 28-day mortality was less than 0.66.⁴⁰ The authors concluded that the hybrid room within the emergency department

was likely to be considered cost-effective for managing patients with trauma who do not have severe traumatic brain injury.⁴⁰

Perspectives and Experiences

Patients

To understand their experiences, Bazzi and colleagues (2020)⁴¹ conducted interviews with 18 patients who required endovascular aortic repair and were undergoing the procedure in a hybrid OR. Being scheduled for surgery made patients feel both hopeful (in knowing their health issue would soon be fixed) and anxious (because of the uncertainty around their procedure). Patients felt relieved after the surgery was complete but experienced unexpected exhaustion.⁴¹ Overall, the participants were not afraid of the hybrid OR environment; rather, they felt it helped to calm them as they trusted the technology and the staff. The nature of the setup of the hybrid OR increased the physical distance between the patient and surgical staff; the authors suggested that having a nurse dedicated to patient care and communication throughout the procedure could help eliminate this distance.⁴¹ Additional patient-centred information could be explored as another way to put patients more at ease leading up to and during these procedures.⁴¹

Providers

Bazzi and colleagues (2021)⁴² also conducted focus group interviews to determine how nursing staff experienced collaboration in a hybrid OR. The nurses and assistant nurses interviewed specialized in surgery, anesthesiology, and radiology. The researchers found that nurses tended to focus on their specific tasks over the interaction of the team and the procedure as a whole.⁴² The participating nurses perceived that there was an uneven division of labour in the hybrid OR and differing perspectives among care staff on patient safety. Collaboration between the nursing teams became better over time but was strained by different terms of employment, a lack of education regarding the specifics of working in a hybrid OR space, lack of joint meetings, and the perceived uneven division of labour.⁴² The authors suggested that proper preparation of staff before beginning to work in a hybrid OR setting could help to ease tension.⁴² Team building activities, training and education sessions, and an adequate balance in team composition could also be beneficial.

Additional Considerations

Facility Planning

The hybrid OR market in Canada is expected to grow at a compound annual growth rate of 10.2% between 2020 and 2027.⁴³ Overall, the number of surgical procedures performed is rising due to an aging population and an increase in the incidence of cardiovascular and orthopedic conditions.⁴⁴ To accommodate the large imaging equipment, hybrid OR spaces typically require a larger footprint than a conventional OR; however, as advanced imaging equipment becomes smaller and more portable in the future, these additional space requirements may not be as necessary.⁴⁵ Increasing the amount of imaging equipment within the hospital may also increase the need for additional imaging staff who are able to work within the OR space. Hybrid ORs are often not used to the same capacity as conventional ORs because the imaging equipment can get

in the way of the movement required for staff or patients for some procedures so they may sit empty some of the time, adding to their per procedure costs.⁴⁵ It is possible that the incorporation of dedicated imaging equipment into the hybrid OR space could minimize the impact of emergency cases disrupting scheduled imaging procedures.

Final Remarks

Although cardiac surgeries, vascular surgeries, and neurosurgeries have been the most common uses for hybrid OR suites, the variety and number of procedures done in these suites is increasing to include orthopedic, gynecological, and other surgical procedures.¹³ It is important to consider present, as well as future, uses when considering building a hybrid OR.¹³ Hybrid ORs appear to contribute to efficient and safe procedures that may benefit patients through decreased recovery times and a requirement for fewer procedures. Radiation safety for both patients and providers remain top of mind when using hybrid ORs.

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Appendix 1: Supplementary Tables

Note that this appendix has not been copy-edited.

Table 2: Summary of Systematic Reviews of Hybrid Operating Rooms

| Author, Year, Objective of Review | Type of Hybrid OR | Number of Publications and Participants | Results and Conclusions |
|--|--|--|--|
| Jin et al. (2022) ²⁰ Systematic review of experiences and challenges of using hybrid ORs for surgery | Hybrid OR as described in each study Imaging modalities used in hybrid ORs were not described | 30 publications (clinical trials, meeting reports, and care reports) including 15,532 patients undergoing general surgery, neurosurgery, thoracic surgery, urology, gynecologic and obstetrics surgery, or cardiovascular surgery | <ul style="list-style-type: none"> The authors of the SR concluded that the use of hybrid ORs could significantly increase success rates and significantly decrease surgical duration Rates of mortality and complications were also reduced when patients were treated in a hybrid OR |
| Spengelink et al. (2022) ²¹ Systematic scoping review of advantages and challenges to adoption of hybrid ORs | Hybrid OR uses including: <ul style="list-style-type: none"> 3D imaging No 3D imaging Surgical navigation Fluorescence imaging | 123 studies describing 44 distinct procedures in 9 clinical disciplines: <ul style="list-style-type: none"> thoracic surgery (n = 43) neurosurgery (n = 37) vascular surgery (n = 21) cardiac surgery (n = 8) urology (n = 6) orthopedic surgery (n = 6) ophthalmology (n = 1) oral and maxillofacial surgery (n = 1) otolaryngology/cervicofacial surgery (n = 1) Cone-beam CT was used in 96% of the included studies and 4% used multi-detector CT | Reported advantages: <ul style="list-style-type: none"> The most frequently reported advantages to hybrid ORs was reported as the achievement of more accurate treatment results Improvements to patient safety Ability to assess treatment result before the patient is closed and associated reduction of re-intervention Ability to combine open and minimally invasive procedures in one OR Reported challenges: <ul style="list-style-type: none"> Elongation of procedure times due to complex patient positioning Increase in radiation dose from 3D imaging No challenges were mentioned in the studies that did not use 3D imaging |
| Khoo et al. (2021) ¹⁷ Systematic review of the efficacy of a hybrid operating theatre in the management of severe trauma | Hybrid OR with mobile fluoroscopy C-arm and angiography capabilities located near the ED | 5 cohort studies comparing patient outcomes (951 patients) in the hybrid OR vs. traditional surgical suites for patients undergoing angiographic procedures or surgery for traumatic injuries | <ul style="list-style-type: none"> 2 of 3 studies found no difference in time to intervention and 1 study found a shorter time for hybrid ORs 4 studies reported mortality outcomes and found no difference for the OR groups 2 studies identified a shorter total procedure time for patients treated in a hybrid OR Decreased transfusion rates were |

| Author, Year, Objective of Review | Type of Hybrid OR | Number of Publications and Participants | Results and Conclusions |
|-----------------------------------|---|--|--|
| | | | <p>observed in 2 of 3 studies that evaluated the outcome</p> <ul style="list-style-type: none"> • One study examined complication rates and identified morbidity benefits for patients treated in the hybrid OR |
| | Hybrid OR with intraoperative MRI with or without angiography | 47 manuscripts (including abstracts and case reports) were included for data collection and analysis | <p>Common anesthetic related safety issues identified included:</p> <ul style="list-style-type: none"> • Lower equipment reliability • Inaccessibility of the patient and airway • Relative isolation of the OR suite in relation to other anesthesia care areas <p>Authors of the individual studies stressed the importance of protocols, safety checklists, and provider training specific to the hybrid OR setting.</p> |

3D = 3 dimensional; ED = emergency department; OR = operating room

Table 3: Studies of Radiation Safety in Hybrid Operating Rooms

| Author (Year), Study Design, Time Frame | Population and Outcomes | Comparisons | Authors Conclusions |
|--|--|---|---|
| Yokota et al. (2022) ³³ Non-randomized prospective observational study February 2020 to July 2020 | Operators and assistants during endocardiovascular surgery in a hybrid OR Intraoperative radiation exposure to the eye (CD/DAP) | Control group (conventional radiation protection) Protected group (conventional protection and a protection sheet [a sterile, disposable drape that does not contain lead and can shield 50% to 95% of scattered radiation]) | <ul style="list-style-type: none"> • The average CD/DAP of surgeons was significantly reduced for the intervention group (5.97 μSV/Gy cm^2 vs 4.40 μSV/Gy cm^2; $P < 0.01$) • The average CD/DAP of surgical assistants was also significantly reduced for the intervention group (1.87 μSV/Gy cm^2 vs 1.01 μSV/Gy cm^2; $P < 0.01$) • The authors concluded that the surgeon's eye is not adequately protected during endocardiovascular surgery in a hybrid OR |
| Jungi et al. (2022) ³⁶ Observational before and after study April 2019 to October 2019 | First operator during endovascular procedures in a hybrid OR Mean unprotected eye lens radiation dose | Exposure to the first operator was measured outside and behind lead glasses and compared to a historical control group from the same hospital measured before | <p>Mean unprotected eye lens dose (outside lead glasses):</p> <ul style="list-style-type: none"> • EVAR = 0.049 mSv (75% lower than control) • TEVAR = 0.042 mSv (79% lower than control) |

| Author (Year), Study Design, Time Frame | Population and Outcomes | Comparisons | Authors Conclusions |
|---|--|---|---|
| | | implementation of a radiation dose reduction program | <ul style="list-style-type: none"> F/BEVAR = 0.175 mSv (55% lower than control) |
| Cerna et al. (2021) ³⁸ Retrospective observational study of prospectively collected data November 2015 to November 2019 | Pregnant people with abnormal placenta undergoing prophylactic internal iliac arterial occlusion in a hybrid OR Estimated fetal radiation dose Risk of radiation induced carcinoma for children born after the procedure | No comparison | <ul style="list-style-type: none"> Mean fluoroscopy time = 1.7 minutes (range, 0.5 to 4.2 minutes) Mean estimated radiation dose to the fetus = 1.49 mGy (range, 0.26 to 3.36 mGy) Mean risk of radiation induced cancer child age = 0.02% (range, 0.01% to 0.04%) |
| Hertault et al. (2020) ⁴⁶ Comprehensive literature review of radiation levels during EVAR in cathlabs and conventional and hybrid ORs 58 clinical studies and 6 reviews Search time frame: 2009 to 2019 | People requiring EVAR DAP/KAP (Gy cm ²) CAK (mGy) Dose to the operator (μSv) Dose to the staff (μSv) | No comparator specified | Standard EVAR: <ul style="list-style-type: none"> DAP in hybrid ORs ranged from 9.17 Gy cm² to 181.99 Gy cm² No studies reported DAP exceeding a threshold of 500 Gy cm² CAK was reported to be between 70 mGy and 983 mGy Complex EVAR: <ul style="list-style-type: none"> DAP ranged from 39 Gy cm² to 696 Gy cm² with 3 studies recording a mean DAP per case > 500 Gy cm² Occupational radiation exposure over the lead apron was low |
| Rehman et al. (2019) ³⁴ Retrospective observational study of prospectively collected data January 2009 to December 2016 | People requiring EVAR Radiation dose (cGy cm ²), screening time, contrast use | Procedures done in a standard OR with a mobile fluoroscopy C-arm (n = 78) vs. procedures done in a dedicated vascular hybrid OR (n = 208) | <ul style="list-style-type: none"> Patients in the hybrid OR group received a significantly lower radiation dose of the standard OR group (16,807 cGy cm² vs 8,233 cGy cm²) Fluoroscopy time was significantly shorter in the hybrid OR Patients treated in the hybrid OR required significantly less contrast for their procedures |

| Author (Year), Study Design, Time Frame | Population and Outcomes | Comparisons | Authors Conclusions |
|---|---|---|---|
| <p>Fidalgo Domingos et al. (2018)³⁵ Prospective observational before and after study January 2015 to June 2016</p> | <p>Surgical team and patients ADAP measured in mSv for surgical team and in Gym^2 for patients undergoing endovascular aneurysm repair, thoracic endovascular aneurysm repair, carotid, visceral, and upper and lower limb endovascular revascularization</p> | <p>Values of absorbed radiation were compared before the installation of a hybrid OR (pre-HOR), after the installation of the hybrid OR and before a radioprotection seminar for the surgical team (PreS-HOR), and in the hybrid OR after the radioprotection seminar (PostS-HOR)</p> | <ul style="list-style-type: none"> • Average amount of absorbed radiation by surgeons was highest during time in the hybrid OR before the radioprotection seminar (PreS-HOR = 1.07 ± 0.4 mSv) • The ADAP for patients was lower significantly lower after the seminar (PostS-HOR = 0.006 ± 0.002 Gym^2) • The authors found the radioprotection seminar was an important part of staff training when using a hybrid OR • The amount of absorbed radiation in the hybrid OR was higher than when using only a fluoroscopy C-arm unit |

μSv = micro-Sieverts; ADAP = average dose-area product; BEVAR = branched endovascular aortic repair; CD = cumulative dose; cGy cm^2 = cumulative Gray-centimetres squared; DAP = dose area product; EVAR = endovascular aortic aneurysm repair; F/BEVAR = fenestrated or branched endovascular procedures; Gym^2 = Gray-metres squared; HOR = hybrid operating room; KAP = kerma air product; mGy = milligray; mSv = millisievert; OR = operating room; Post-S = post-seminar; Pre-S = pre-seminar; TVAR = thoracic endovascular aortic repair.