Comparing C-arm Capabilities Compassionately

Lower exposure; raise value.

Contents

Introduction:

Hello, and welcome to this simple guide designed to maximize the utility of your next C-arm purchase. This guide has been designed especially to familiarize the busy professional in the medical facility management field with the fundamental knowledge required to optimize the use of C-arm imaging technology.

Like all beautiful things, this optimization may be readily achieved through the application of a simple axiom: Lower exposure; raise value. This describes the cardinal rule for machine selection when purchasing any form of radiation-producing equipment.

Why is conscientious C-arm management important?

Minimally invasive procedures are driving the growth of a strong market for C-arm technology. The global market for fluoroscopy and mobile C-arms was estimated at 9,403 units in 2011, and is projected, by Global Industry Analysts, Inc, to grow to 11,486 units and $1.4 billion by 2017. While the existing regulatory framework ensures that bare minimum checks on radiation over-exposure are carried out, it nonetheless behooves the conscientious business administrator to understand the radiological impact of their hardware's operation on their staff and clients.

While C-arm purchasing in developed markets like Western Europe and the United States, which represent the largest markets worldwide has been fairly steady, in emerging markets including China, Brazil, Russia and the Middle East, business is picking up pace, ensuring that the future of global medicine will involve many more C-arms than are currently installed.

What about C-arms makes them formidable?

C-arms are specialized medical diagnostic equipments which employ overhead x-ray image intensifiers. These intensifiers provide allow detailed viewing of anatomic structures in real time using fluoroscopic dyes. As non-invasive devices, they offer safe screening before, during and after all manner of procedures. While minimal invasiveness allows faster diagnosis and treatment, as well as increased comfort for patients, it comes at a cost, on a pair of different axis. The first of these is simple monetary cost; there are fixed price tags associated with every different component involved in a modern C-arm setup. The second cost is radiation exposure itself. Limiting radiation exposure is not merely healthier for your patients; it saves good money, as each extra rad pointlessly squandered on overly powerful or detailed imaging is both exponentially expensive and cumulatively more dangerous.

Exposure considerations are a primary consideration in most state's licensing regulations for C-arm operation, and ought to be that of engaged facilities managers as well. Compliance beyond minimum legal standards provides your facility with a comfortable shield against potential liability at the same time as it protects staff and patients from undue exposure. As C-arm machines are mobile and easily transportable, it is important to consider exposure protection for all associated spaced.

Shielding, however, is only one of the ancillary costs associated with C-arm implementation. C-arms work in conjunction with patient tables that have been specifically designed for X-ray

transparency. These allowing free positioning of the C-arm around the patient in different orientations, allowing all different parts of the anatomy to be scanned as needed. Some are even designed to move and rotate. This allows better patient access, increased imaging angles and greater stand-off distance between staff and C-arm equipment, which decreases wasted rad exposure.

As tables need to be X-ray translucent to avoid interference with imaging, the can be a considerable cost in their own right, and should be evaluated for needed and superfluous features specific to the specialists operating in your facility. C-arms find use in a wide variety of different medical specialties, including radiology, surgery, cardiology, podiatry, urology and gynecology. They are especially apt for allowing users to view and monitor the placement of pacemakers, catheters and other prosthetic devices, as they provide a detailed near-field view of the area of operation,

C-arms all offer a suite of basic radiographic capabilities, but they are primarily used for fluoroscopic imaging.

The parts of a C-arm:

Image Intensifier

The image intensifier is the primary component which separates C-arms from other radiation-based medical devices. While it puts out no radioactivity itself, it acts as a collector for radiation generated by the device's generator, converting the projected x-rays and the shadows cast by the patient's body into a usable image. This image can then be displayed on screen, printed to paper or film, or shared digitally with your facility network, as per the capabilities of the particular C-arm being used.

Image intensifiers can be set up for plain fluoroscopy or digital subtraction angiography, but they all offer adjustable radiation levels to allow for fine-tuning the exposure to the particular part of the body being analyzed. For example, in simple fluoroscopy, imaging of the wrist would not require the same amount of exposure as the abdomen.

The image intensifier is often referred to with the simple acronym "I.I." and is usually rated in terms of both sensor size and magnification options. As image intensifiers require rads from the generator to illuminate their viewfinders, larger sensors call for greater radiation exposure and, therefore, considerably more over-all lifetime cost for the purchased machine as an asset. For this reason, it is important to determine precisely the usage case scenario for the C-Arms you wish to acquire. As these machines are designed to serve a wide customer base in all medical and even non-medical fields of application, no one set of specifications can be suggested; rather, the axiom about minimization should be scrupulously followed.

Planning precisely which type of procedures your future C-Arm will perform on a regular, profit-earning basis will allow you to best determine how much excess radiation cost leakage and patient exposure liability best meets your state's particular regulatory environment.

Once you have articulated your facility's business case for this capital outlay in a procedure-by-procedure accounting of the expected use patterns, you'll be ready to begin selecting appropriate major components which will comprise your ideal C-arm unit for that particular application.

Digital subtraction angiography is a feature of some image intensifiers. It allows preset programs from the user to dictate rate of how many images are captured and displayed every minute. Increasing this frame rate makes displayed video of the observed area smoother, but also increased dollar and rad costs.

Image intensifiers found on modern C-arm equipment are commonly either 9" or 12", with Siemens also manufacturing a specialized 13" model for some applications. They are primarily "tri-mode" view-finding devices, capable of focusing their observation over a smaller region to achieve a resultant magnification of the x-ray illumination.

9" image intensifiers comprise the preponderance of currently-available C-arms. They are widely used for cardiac, orthopedic, pain management, general surgery pacemaker placement and sports medicine. 12" image intensifiers, on the other hand, are used almost exclusively in

the vascular and neurovascular field, although they may be used for complex orthopedics as well. 12” I.I.’s are more costly, but they offer considerable advantage in some procedures; extra inches of diameter allow operators to scan more of the body at once, and this can enable run-offs and other specialized procedures which are not possible on a single run with a 9" unit.

The other important factor in I.I. selection is the magnification modes. Although both 9" and 12" systems hove tri-mode image intensifiers, the relative magnification levels they offer are often not directly comparable. OEC, as an example, produces 12" I.I.’s which offer zoomed image areas of 12/9/6, while their 9" units can focus on targets in a 9/6/4.5 inch bracket. Thus, the smaller 9" systems actually offer greater magnification, and so OEC only makes their cardiac platform with a 9" I.I. Generally, specialized practitioners doing delicate work will find higher magnification more beneficial than a wider field of view. Thus, those who wish to have rads and dollars from their C-arm budget would to well to consider 9” I.I.s for all C-arm installations not specifically relating to vascular work or multi-limb simultaneous imaging.

The Image intensifier is affixed to an imaging system unit which can perform a variety of movements applicable to different surgical procedures. This, in turn, is compact and lightweight, to allow easy positioning with a wide range of motion and adequate space for staff to work around, while remaining firm enough to avoid misalignment.

X-Ray Generator

Penetration power is measured in rads and rads, as stated, incur costs. Therefore, the penetration power of your potential C-arm should not exceed that required to achieve its visualization objectives. The X-ray Generator is the C-arm component which puts out radiation, and so its specifications should be of primary concern when exercising corporate governance. Penetration power is integral to the operational capabilities of a C-arm. Furthermore, trends suggest that patients are becoming larger, and larger bodies require greater penetration power to image correctly. In general, facilities focused on the extremities have no need for higher-power generators.

X-ray generators on the market today primarily operate at 20,000 cycles per second with kVp settings from 40kV to 120kV. During fluoroscopy examinations a tube current of 0.1mA to 6mA is common, while in radiographic mode it’s fixed between 20mA to 60mA. Other radiographic applications can widen this range, anywhere from 0.16 to 160 mA. Exposure lengths can be set anywhere from 0.1 seconds up to 4.

While the costs are there, the benefits from more rads are also evident. Higher peak throughput does allow greater flexibility in imaging, reducing exposure times and the need to re-take long-exposure shots. Flexibility increases the quality of care which can be afforded to pediatric, obese and other specialty-concern patients.

X-ray generators produce illuminating x-rays from a device known as an x-ray tube. There are two types of X-ray tubes; fixed anode and rotating anode. Fixed anode tubes can handle only roughly $1/10^{th}$ the heat exposure of rotating anode tubes. Rotating anode tubes also offer a

0.3mm focal spot, far tighter than the fixed anode's 0.5mm fluoroscopic focal spot and 1.8mm radiographic focal spot.

Workstation Unit

While it is the large, C-shaped support arm of the device from which the C-arm draws its name, it is this other, "forgotten" component which houses the true diagnostic prowess. The workstation unit houses the "guts and brains" of any C-arm setup, and these can range from simple and antiquated to cutting edge and overwhelming. The workstation unit is can contain all manner extensive customization options and model-specific stock features, including various handles for movement and positioning, power switches, exposure switches, cable hangers brake pedals, controls for radiographic and fluoroscopic settings, interconnect cables, mechanical, optical or non-volatile electronic storage drives, optical disk writers, PACS hardware, and advanced image quality enhancement processors capable of noise reduction and zoom control.

Workstation units need to be differentiated by more than just hardware; there are a variety of software and applications suites available for different C-arms, each requiring different particular hardware configurations in order to operate properly. Inevitably, certain procedures will call for more features than others, but it should be remembered that each specialty requires only a given set of options complete their work. While it is important to consider the possibility of increased feature need as practices expand, remember that unused extra options represent nothing more than sunk costs. In general, a C-arm for a busy regular surgery should need little more than some basic image enhancing; Edge enhancement, Averaging, Digital Spot and Pulsed Flouro. High-use general surgeries, especially those in emergency medicine, also benefit from increased image storage capacity, digital zoom and roam. For vascular surgery, Digital-Subtraction Angiography capabilities should be added, as well as Roadmapping and 15fps Cine view. 30fps Cine View is also a (costly) option, one which is of little practical benefit outside the cardiac and neurovascular fields.

What to buy?

Buy based on your best needs analysis

Now that you know a little bit about the capacities of different C-arm components, and the appropriateness of particular technologies to individual specialties, you are ready to determine which C-arm you wish to acquire, and under what terms.

The wide installed base of existing C-arms ensures that there is always a healthy market of refurbished machines available alongside to compliment the various new models introduced to the market every year. In addition, some facilities now find it more economically fesable to rent or lease C-arms, as this provides added flexibility with regards to rapidly accelerating technology. Such leased units frequently find their way back into the refurbished market at a significant discount below their original price-tag.

Once you've determined which type of C-arm you require, the next step is to find a good place to acquire it. While purchase of a brand new machine can be costly, it is considerably simpler than the process required to obtain a valuable C-arm asset through a refurbishment program. That process is outlined here, in order to provide the reader with valuable knowledge that will also inform the decisions involved in purchasing brand new C-arms.

The value of vendor research

The first pillar of good purchasing is vendor research. The basic principle of vendor research is: Ask Everything.

There is no question you should leave unanswered. Competent vendor will be able to comfortably answer any questions you have, while those who are unable to talk emphatically about the features important to your buying decision don't deserve your time of day.

Of primary concern when dealing with a refurbished equipment supplier is their own refurbishment process. Ask for verifiable documentation of the steps they take. IS0 certification demands that this be a document which they have on hand, but uncertified vendors should also be capable of producing such a work manifest.

Common understanding dictates that a qualified refurbishment programs should include each of the following steps::

Refurbishment checklist

Evaluation: This step involves examining the C-Arm's regular functioning, compiling a list of the components which must be repaired or replaced. Common evaluation practice includes a Piranha radiation-quality assessment, confirmations of the tube, image intensifier and image save functionality; as well as general and tube performance, ABS, and resolution testing.

Decontamination: This step involves the removal of any potential biohazards. It should involve internal and external cleaning with complete removal of the exterior equipment housing. A wide-spectrum decontamination should be performed, and all data-storing devices in the C-arm

should be wiped and formatted to remove any residual patient data, in accordance with HIPAA directive.

Reconditioning: This step involves restoring the original look of the device's body to its original state. It calls for the equipment housing covers removed during decontamination to be prepped for painting, with all dents and scratches removed. All parts of the device should be completely repainted, with and new decals, key pad overlays and logos placed as per specifications from the manufacturer. .

Repair & Replace: This step involves functional resetting of the C-arm device. All damaged components identified in the **Evaluation** need to be repaired or replaced. New monitors and batteries should be installed, and new replacement parts used for any damaged damaged high voltage cables, brake pads, foam seals, switches, connectors, breakers, fuses or wheels.

Calibration: This step should be performed prior to delivery of the newly-reconditioned device. It is designed to to ensure that C-Arm is performing correctly. A thorough technical calibration should include dose adjustment, beam alignment, vertical column, power supply, steering, locks, handles, collimator, battery charger, video system and the bearings for the arm itself.

Timeframe is an important consideration, and you would be wise to ask your C-arm vendor upfront about theirs. When purchasing a refurbished unity, everything should be checked. Suppliers who quote less than two weeks time to recondition a unit following its sale are likely cutting corners somewhere in the process. As transit time can be a considerable portion of the total delay between purchase and installation, seven to ten day turnaround should only be expected for new units, or units which have already been through the complete (and documented) refurbishment process.

Most refurbished C-arms from reliable refurbishers come with an RTI Piranha Dosimeter report which documents recorded performance and calibration specs. Being proactive about requesting these documents and inspecting them yourself can both ingratiate you to your vendor, and help you maintain an active understanding of the over-all rad use across your facility. They are also often required when a licensed physicist inspects your C-Arm for compliance with state regulations after your installation is complete.

If you are not available inspect the C-arm in your vendor's facility prior to its release to your institution, be sure to send someone who can. Having "boots on the ground" prior to the completion of the sale will help ensure their best effort.

In addition, ask your supplier to send you photos which demonstrate the cosmetic condition and overall cleanliness of the unit post-refurbishment. The vendor should be instructed to include close-in and wide-angle shots of the serial number tag, to verify against the numbers listed on the sales agreement. Vendors should also be instructed to send a series of six photos that demonstrate the image quality of the C-arm; three images of the monitor displaying a blank field, at normal, mag1 and mag 2 settings, and then three images of a metal object such as a coin or key shot at the same series of magnifications.

Once the unit arrives at your facility, it's time for the in-house inspection. This final portion of your due diligence involves inspecting the delivered C-Arm unit in your own facility. The first step is a complete system inventory. Using your sales documentation, compare what was delivered to what was listed. Small items like foot-switches, printers and skin spacers can be easily misplayed. If parts are missing from the manifest, contact the vendor immediately and have them make not of the incomplete delivery.

If the delivery is complete, you can power on the C-arm system and attempt to replicate the six display images you received from the vendor prior to shipping. Vibrations during shipping can cause unremoved dust to occlude the imaging path. Checking the image will also confirm that the other components involved in the imaging process (the high voltage circuit and x-ray tube) are functioning correctly. .

Ideally, you shouldn't be afraid to ask your vendor anything you wish for, including to demonstrate what they intend to do and what they have done in the past. This is a brilliant way to avoid ending up in a long-term contract with a vendor who is underperforming. Ask specifically about rads, about how you can get the most useful imaging while throwing of as few of them as possible. A competent vendor will know enough to couch all their sales discussions in terms of both fiscal and exposure costs.

How much should it cost?

This is the final determinant for your purchasing selection. How many rads are you planning to put out, and how much will it cost you to put them in the right places?

Prices and rad levels vary widely, with price tending to depreciate almost immediately after purchase of new unit (much like an automobile) while functionality remains the same. The current price range for used and refurbished C-arm imaging devices runs from $5,000 to $140,000, with prices for new units ranging up to $200,000.

The wide number of different models, features, and associated services make it very difficult to project the anticipated cost of a given unit for a given purpose without first building a list of specifications. This is the process of evaluating your machine's expected use which was discussed earlier in this document. The prices for older models tend to be significantly lower, given their age and their relatively limited feature-sets. Late-model versions with many features, conversely, can be quite costly, even after significant reconditioning.

It is important to remember to factor in additional cost for reconditioning, delivery, install, depending on your proximity to the vendor and the condition of the system and your proximity to your vendor. Over-all price should be determined by what features you really need. Be sure to take possible expansion of practice in the future into consideration.

Other Costs

The costs will grow to include more than simply the onboard option bundle you ultimately decide upon. Some accessories are common enough to bear noting; Printers, DICOM boxes and C-arm tables will definitely inflate your costs further.

Used printers for medical imaging C-arms can cost up to $5000 themselves, depending on the size and media of the prints produced. Low-end images can be produced cheaply on Polaroid paper, while the middle-capacity machines usually use film printers in he 8"X10" size. Most expensive are high-end printers that print on both paper and film in sizes up to 11"X14".

A DICOM system allows your C-Arm to send its images to other viewing stations on your network. While newer C-arms usually include an on-board DICOM unit, older models often require a seperate DICOM box to enable this functionality. A used DICOM box can be bought for around $3,000, while a band new one costs approximately $12,000. DICOM alloes interface with a standard PACS system, allowing you to make multiple imaging devices available for independent viewing by users across your system. .

C-arm Table

The most expensive C-arm accessory is the C-arm table. This price can range widely, and is a factor of style, weight capacity, and articulations. The high cost of these components stems from the requirement that they be completely constructed of X-ray-invisible materials.

A brand-new, basic "diving board" style table will cost between anywhere between $8,000 and $20,000, with movement capabilities being the primary price consideration. Float style tables, however, being newer and more suited to vascular surgery, cost anywhere from $25,000 to $40,000 dollars.

At the high-end of the scale are bariatric tables, large-capacity models which have increased patient weight handling at or near the 1,000 pounds mark. These tables commonly retail in the $25,000 to $35,000 range.

Prices for used tables on the secondary market are a little better, with most reconditioned tables usually selling for anywhere from 25% to 35% less than the comparable model direct from the manufacturer.

Other cost considerations

In addition to the components listed above, there are a number of other expenses to consider as part of your over-all G-Arm installation price. Although most of these are required to operate your C-arm safely and effectively, they may not be included or even sold by all C-arm resellers in the market.

Radioactive shielding is deathly important. It must be provided for all staff who work near a C-arm. Aprons can average $200-300 each, while google start at $55 per pair and can cost up to $250 per pair for the best protection available. Shielded gloves cost anywhere from $130 to $250 per pair.

Your facility will also have to be inspected and certified by a physicist after each new C-arm install. The price for this cost, which is required by federal mandate, is up to the individual independent physicist providing the service, and so you can best negotiate it with an inspector near you location. You can find these contractors by contacting your state Department of Health.

The Department of Health will also provide you with their specific regulations regarding the level of lead shielding you need in your facility for C-arm operation. This can vary widely from state-to-state; while n some locations portable shields and aprons are all that is called for, in others, leaded drywall or other facilities shielding apparatus might need to be hung. Again, your state's particular DOH can direct you.

A C-arm is a large investment, even for a well-monied institution. It can be quite beneficial, in your role as governing agent of your institution, to protect such a costly investment investment with some type of warranty or service plan. The the quality and cost of such plans can vary significantly from vendor to vendor, and so considering coverage is an important part of your initial vendor research. Be sure, when selecting a coverage plant, that all major components included. If you have your own engineering staff, a parts-replacement only agreement would alow you to protect your machines' longevity without the burdensome cost of vendor-supplied support techs.

Conclusion:

So, now you know what we know about C-arms, how they work, what to look for in them, and how to arrange to buy on.