CHAPTER 15

Management of Complications in Complex Coronary Interventions

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Introduction

Percutaneous coronary interventions (PCI) may result in complications that can be grouped into 3 broad categories: coronary, cardiac non-coronary, and non-cardiac (**Figure 1**). Coronary complications consist of either coronary artery occlusion, coronary perforation and equipment loss or entrapment. Other cardiac complications such as arrhythmias may be due to coronary complications (for example coronary dissection may lead to ischemia that can in turn lead to ventricular tachycardia or fibrillation) or may be unrelated to coronary artery issues. Non-cardiac complications, include access complications, thromboembolic complications (such as stroke), contrast-related complications (such as contrast nephropathy and hypersensitivity reactions), and radiation-induced skin injury.

Clear understanding of what can go wrong during cardiac catheterization is critical for both prevention and early treatment of possible complications. In this chapter, we will review some of the most common complications of PCI.

Acute vessel closure

Acute closure of a coronary artery may lead to severe ischemia and can occur through various mechanisms, such as dissection (**Figure 2. Panel G and H**), intracoronary thrombus formation (**Figure 2. Panel I**), plaque/thrombus/air embolization (**Figure 2. Panel I and K**), no-reflow phenomenon, or coronary spasm. Determining the cause of the acute closure is critical for providing optimal treatment.

Dissection

In non-CTO PCI, the most common reason for coronary dissection is the use of atherectomy, high pressure balloon inflations, cutting/scoring balloon inflations, or guiding catheter-induced trauma. In case of dissection, it is critical to maintain wire position, as rewiring can be challenging due to repeated guidewire entry into the subintimal space. (**Figure 2. Panel G and H**).

If guidewire position is maintained into the distal true lumen, dissections are treated with stent implantation; however, stent delivery can be challenging in some of these cases requiring use of a guide catheter extension or anchoring techniques to improve guide catheter support.

If guidewire position is lost, rewiring is required, which can be challenging, often requiring use of the “parallel wire” technique and various types of guidewires. If the guidewires do not cross into the distal true lumen, re-entry may be required, for example by using a reentry system device[1] or by using retrograde crossing if there are appropriate collaterals.[2] Intravascular ultrasonography can be very useful for confirming distal true lumen wire position.

A special type of “dissection” is intramural hematoma. Intramural hematomas can rapidly extend distally, hence placing a stent distal to the hematoma is important to block distal propagation.[3] Subsequent treatment consists of stenting over the hematoma or using a cutting balloon to fenestrate the intimal layer releasing the hematoma.[4]

Distal embolization and no-reflow

Distal embolization may be due to plaque, thrombus, or air and is more likely to occur when treating highly lipidic lesions and lesions with large thrombus burden. Embolic protection devices have been shown to reduce the risk for peri-procedural myocardial infarction during saphenous vein graft PCI, but their use in other settings remains controversial. Intracoronary vasodilators can be administered both for prophylaxis ("chemical protection") and for treatment if distal embolization occurs. Aspiration of the embolized material can also be useful. In case of air embolization, administration of 100% oxygen can help with restoring flow, along with aspiration in case of large embolization.

Coronary no-reflow usually occurs when acutely occluded vessels are re-opened, through several mechanisms, such as myocardial injury due to prolonged ischemia, endothelial dysfunction, spasm, and distal thromboembolism. No-reflow mostly occurs in patients with ST-segment elevation myocardial infarction, in saphenous vein graft interventions, or after use of rotational atherectomy.[5] The following two interventions are key for the management of no-reflow: (a) aspiration if distal embolization is suspected; and (b) intracoronary injection of vasodilators (such as nicardipine, nitroprusside, adenosine, verapamil, diltiazem) and possibly glycoprotein IIb/IIIa inhibitors. Stent placement should be delayed until after TIMI 3 flow is restored, or possibly postponed for another day if poor flow remains after vasodilator administration and aspiration.

Spasm and pseudolesions

Spasm can lead to severe lesions and even vessel occlusion, hence it is important to routinely administer nitroglycerin before coronary angiography (unless patient is hypotensive).
Guidewire advancement through highly tortuous vessels (for example left internal mammary artery grafts or native coronary arteries) can lead to vessel straightening and appearance of severe lesions (pseudolesions). Guidewire removal (or withdrawal so that the soft distal part of the guidewire is within the tortuous segment) can help determine whether a lesion is "true" or represents a pseudolesion.

Perforation, pericardial tamponade

Coronary perforation is one of the most feared PCI complications[6] and is more common in chronic total occlusion PCI (**Figure 2 Panel A and B**). There are 3 major perforation types: large vessel perforation, distal vessel perforation, and collateral vessel perforation. Large vessel perforations are usually immediately obvious due to extravasation of a large amount of blood into the pericardium, whereas distal vessel and collateral perforations may be challenging to diagnose due to slow blood extravasation. Occasionally, distal vessel perforations may not be diagnosed until several hours later, when slow accumulation of blood into the pericardial space leads to tamponade.[7] We recommend a step-by-step approach for managing coronary perforations (**Figure 3**).

"Universal algorithm"

The very first step in any perforation type is to inflate a balloon proximal to the perforated segment to stop bleeding into the pericardium. If this is done early, the size of the pericardial effusion may be small, possibly obviating the need for pericardiocentesis. Intravenous fluids and/or pressors should be administered if hemodynamic instability develops and emergency pericardiocentesis may be needed in case of tamponade (with re-infusion of the aspirated blood through a peripheral vein). Alerting the cardiac surgeons early may be beneficial in case emergency surgery is needed, although this is required in very few cases. Anticoagulation is usually not reversed in case of perforation, because it may lead to coronary thrombosis that may be harder to treat than the perforation itself. Anticoagulation can be reversed at the end of the case after all equipment (guidewires, balloons, etc.) has been removed from the coronary arteries. Sometimes, balloon occlusion alone may lead to adequate perforation sealing (especially for smaller perforations). If, however, pericardial bleeding continues, definitive treatment may be required, which is customized to the type of perforation.

Large vessel perforation

Large vessel perforations are usually treated with implantation of a covered stent. The Graftmaster stent (Abbott Vascular, Santa Clara, CA, USA) consists of 2 bare metal stents and a polytetrafluoroethylene membrane sandwiched between them. The Papyrus stent (Biotronik, Baar, Switzerland) is an alternative option and has a favorable deliverability profile. Use of guide catheter extensions (usually 8 French for Graftmaster) and other support techniques may be needed to facilitate deployment of the covered stent to the target lesion.

To minimize pericardial bleeding, inflation of the “blocking balloon” is maintained until the covered stent is ready to be delivered and deployed. This can be achieved through a single 8 French guide catheter (block and deliver technique)[8] or using 2 guide catheters (“ping-pong” or “dual guide catheter” technique). Covered stents should be post-dilated at high pressure to optimize stent expansion and reduce the risk for restenosis and stent thrombosis.

Distal vessel perforation

Definitive treatment of distal vessel perforations is usually achieved with embolization (of fat or coils in most cases). Embolization can also often be performed by using a single large guide catheter through which both a balloon (for blocking flow into the pericardium) and a microcatheter (for delivering fat or coils) are advanced. Fat can be harvested through a small incision in the groin or around the femoral access site; it is dipped into contrast (to render it radio-opaque) and injected through a microcatheter. Multiple fat pieces may need to be injected to achieve hemostasis. Coils are also delivered through a microcatheter. Most commercially available coils are 0.018 inch compatible, which means that a different, peripheral microcatheter may need to be used instead of the commonly used coronary microcatheters. There are, however, 0.014 inch compatible coils that can be delivered through standard 0.014 inch microcatheters. Detachable coils (that can be released using a special device once positioned in the desired location within the coronary artery) are preferable to pushable coils (pushed through the microcatheter without being able to control the final position).

An alternative to embolization for treating distal perforations is use of a covered stent to cover the origin of the perforated branch. However, this is usually reserved for cases in which embolization is not feasible, for example perforation of very small branches.[8]

Collateral perforation

Crossing of collateral vessels during chronic total occlusion PCI may result in perforation, which is usually treated with embolization, similar to distal vessel perforation. However, embolization may often need to be performed from both sides of the perforation to achieve hemostasis. Very small (<0.5 ml) amounts of thrombin have also been successfully used in this setting.

Device loss and entrapment

Various equipment, such as stents and guidewires, may get “lost” or entrapped within the coronary vasculature. Stents may separate from their delivery system, usually when trying to advance them through highly tortuous and calcified lesions or when withdrawing them in the guide catheter. Guidewires can get entrapped within the vasculature (or sometimes behind stents) leading to guidewire fracture and retention upon attempted withdrawal.

The risk for stent loss can be decreased by meticulous preparation of the target lesion and by use of guide catheter extensions. If stent loss occurs, the first consideration is whether it needs to be retrieved or whether it can be deployed or crushed at the site of loss. The latter may be the preferred approach, if no major side branch or critical coronary location (such as left main) are involved. Maintaining guidewire position within the lost stent facilitates subsequent management. If the stent is lost in a non-critical location, it can be deployed. If retrieval is desired, the simplest technique is using the "small balloon technique", in which a small (1.20 – 1.50 mm) balloon is advanced through the lost stent, inflated and then retrieved, dragging along the lost stent. Another technique involves advancement of two or more guidewires distal to the lost stent: the guidewires are twisted rapidly and then removed, hopefully together with the lost stent. Use of snares is another technique for stent retrieval.

If a guidewire becomes entrapped, it is critical to resist the temptation to pull hard on it, as this may lead to guidewire fracture and unraveling of the guidewire coils, which can extend into the aorta and require cardiac surgery for removal. It is best to advance a microcatheter, small balloon, or guide catheter extension to facilitate guidewire retrieval. If the guidewire fractures, use of intravascular imaging can help determine whether guidewire unraveling has occurred and how far it extends. If the guidewire fragment(s) do not extend into the aorta, covering them with stent(s) can help obviate subsequent complications.

Non-cardiac complications

Systemic thromboembolic complications

Catheter advancement through heavily diseased vessels (such as the ascending and descending aorta) may lead to plaque or thrombus embolization, potentially leading to stroke, bowel ischemia (due to superior or inferior mesenteric artery embolization), renal, and lower extremity infarction. Use of long sheaths, 0.065" guidewires for guiding catheter delivery and careful back-bleeding and aspiration of the guiding catheter can minimize the risk of peripheral embolization.

Vascular access complications

Arterial injury at the access site is more common with the femoral approach and may lead to bleeding (such as retroperitoneal bleeding) or ischemia (acute limb ischemia). Use of radial access and ultrasound guidance, fluoroscopy, and micropuncture needles can help decrease the risk for access-related complications.[9] Retroperitoneal hematoma should be immediately suspected in case of hypotension after cardiac catheterization, followed by immediate computed tomography angiography (initially without and then with contrast if retroperitoneal bleeding is diagnosed to determine the presence of active bleeding). This may then help guide endovascular or surgical treatment.

Radiation injury

Radiation skin injury is an infrequent complication of percutaneous coronary interventions, but occurs more frequently in complex interventions requiring long fluoroscopy and cineangiography times. Radiation exposure can result in deterministic (acute and chronic radiation skin injuries) and/or stochastic (cancer, hereditary effects) complications. Pre-, intra-, and post-procedural strategies to reduce radiation-associated risks are summarized in Table 1. In case of >5 Gray air kerma (AK) radiation dose, patient notification and education, close post-procedural patient monitoring, and communication with the primary care provider are critical for detecting possible radiation injury and promptly initiating treatment.

Contrast induced complications

Contrast induced nephropathy is more common in patients with baseline kidney disease and diabetes, especially when large volume of contrast is administered. Pre-procedural hydration, use of iso-osmolar contrast media, and limiting contrast volume to <3.7x the patients' creatinine clearance can help minimize the risk for contrast nephropathy. Staging complex procedures and using intravascular ultrasound can also help minimize contrast volume: zero-contrast PCI has recently been described by experienced operators.[10]

Use of contrast can also lead to allergic reactions. Patients known to have contrast allergy should be pre-treated with steroids (usually prednisone 50 mg 13, 7 and 1 hours before the procedure; diphenhydramine 50 mg 1 hour prior to the procedure; and cimetidine 300 mg orally or ranitidine 150 mg orally 1 hour prior). Alternatively, 32 mg of methylprednisolone can be administered 12 and 2 hours prior to the procedure together with diphenhydramine as described above.

Chapter 15: Management of Complications in Complex Coronary Interventions

Figures

Figure 1: Classification of complications associated with percutaneous coronary interventions.

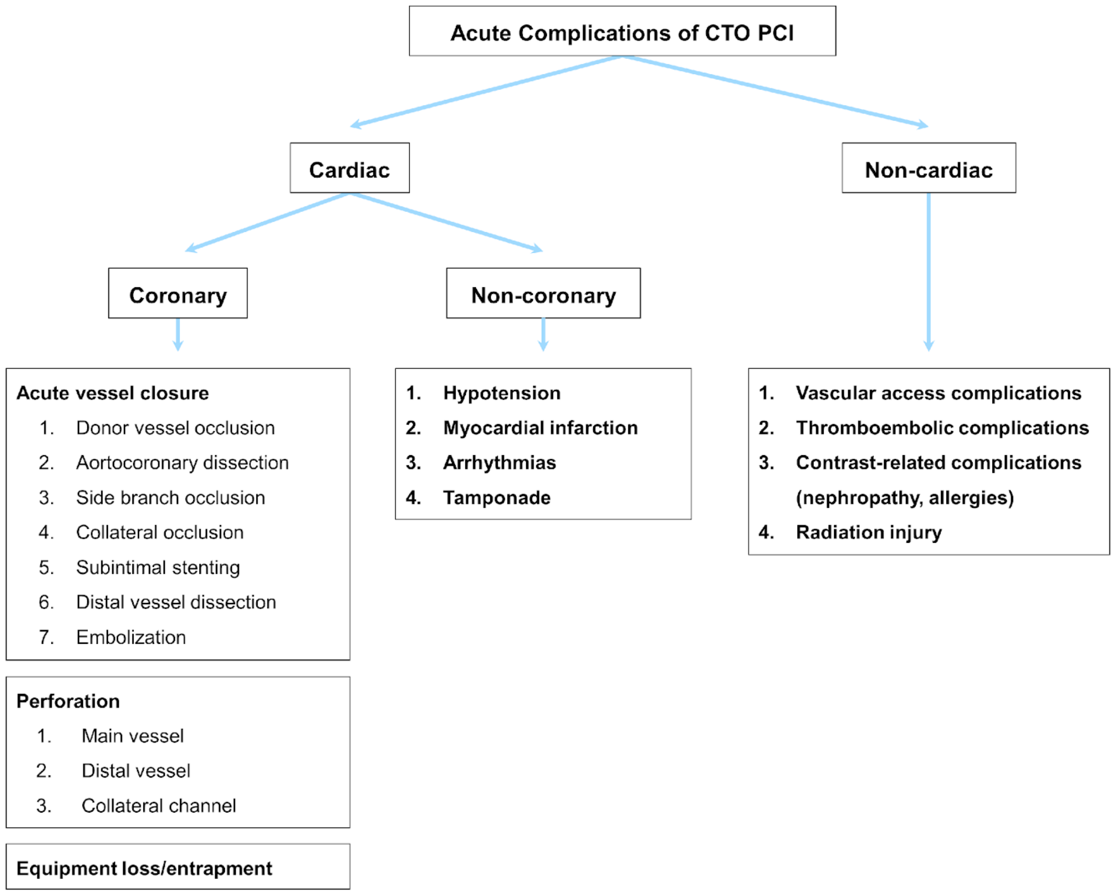

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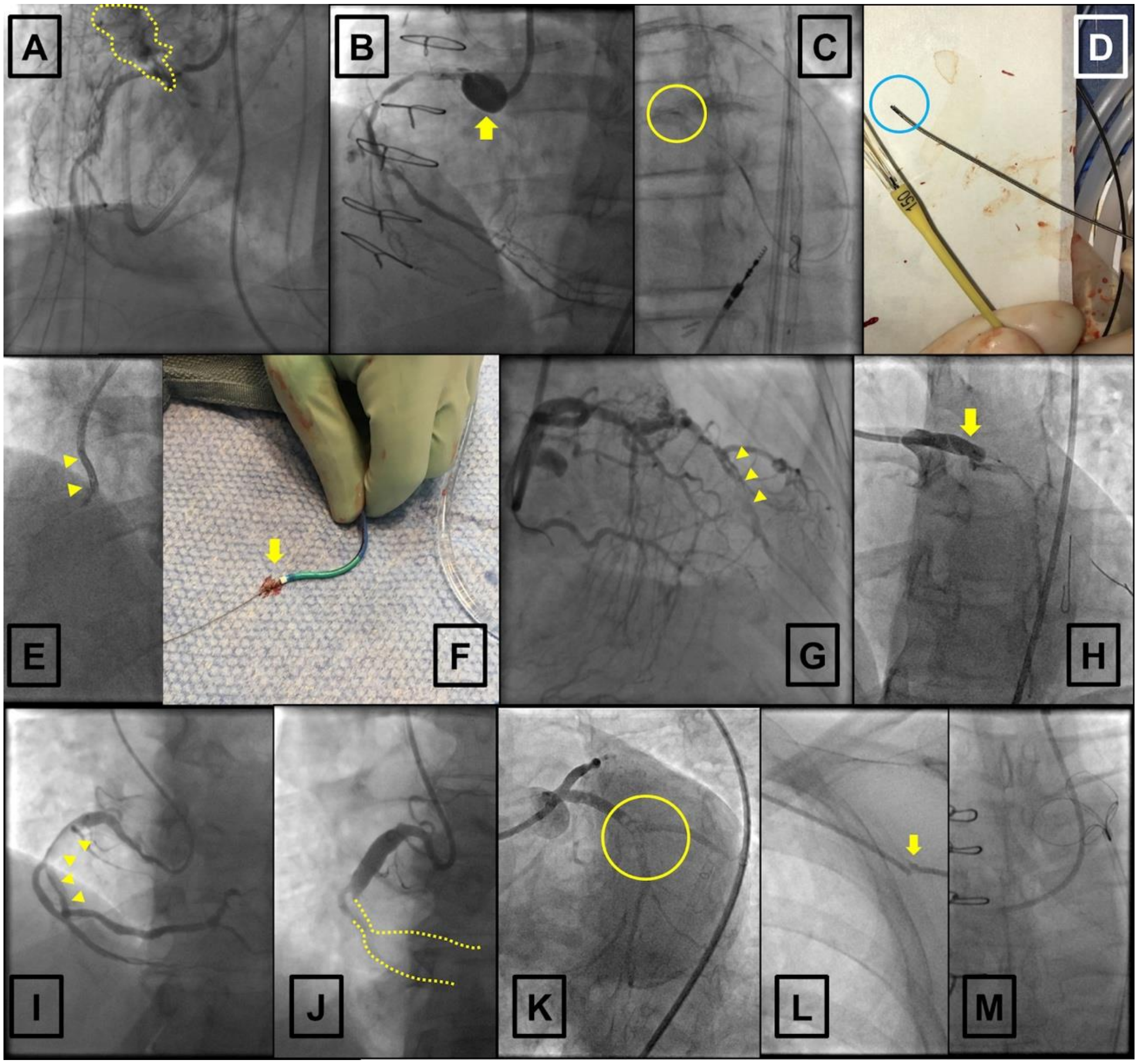
Figure 2: Examples of various complications associated with percutaneous coronary interventions.



Panel A: Coronary perforation of the proximal right coronary artery. The perforation was successfully sealed using covered stents.

Panel B: Aortocoronary dissection (arrow) due to wedged guiding catheter during retrograde CTO PCI. A stent was placed in the right coronary artery ostium. Post-procedural CT angiography did not demonstrate extension of the dissection.

Panel C and D: Broken microcatheter tip during retrograde chronic total occlusion intervention, that was successfully retrieved using a guide catheter extension.

Panel E and F: Stent loss during PCI of a right coronary artery lesion. The stent was removed using deep guide intubation and balloon trapping.

Panel G: Acute vessel closure due to mid left anterior descending artery (LAD) dissection. Re-entry into the distal true lumen was achieved using the Stingray balloon resulting in successful recanalization.

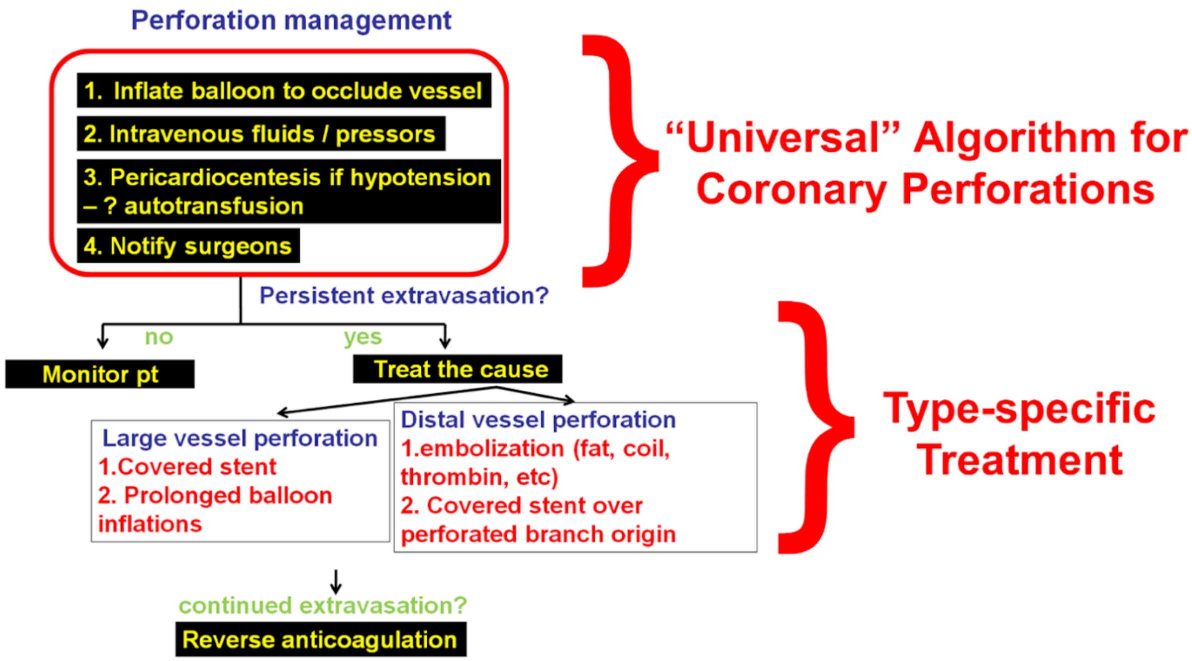
Panel H: Acute dissection of the left main coronary artery leading to cardiac arrest.

Panel I and J: Large thrombus in the right coronary artery. Aspiration attempts led to distal embolization.

Panel K: Air embolism during PCI of the circumflex. The air dissolved and flow was restored after administration of 100% oxygen.

Panel L and M: Entrapped left radial guiding catheter due to kinking in the subclavian artery. The tip of the kinked catheter was snared and untwisted leading to successful retrieval.

Figure 3: Treatment algorithm of coronary perforations.



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Tables

Table 1: Radiation dose management in cardiac catheterization laboratories.

I. Pre-Procedure

A. Radiation safety program for catheterization lab
    1. Dosimeter use, shielding, training/education
B. Imaging equipment and operator knowledge
    1. On screen dose assessment (air kerma, DAP)
    2. Dose saving: store fluoroscopy, adjustable pulse and frame rate and last image hold
C. Pre-procedure dose planning
1. Assess patient and procedure, including patient's size and lesion(s) complexity. Examine patient for potential skin injury from prior high dose cases.
D. Informed patient with appropriate consent

II. Procedure
A. Limit fluoroscopy: step on pedal only when looking at screen B. Limit cine: store fluoroscopy when image quality not required C. Limit magnification, frame rate, steep angles D. Use collimation and filters to fullest extent possible E. Vary tube angle when possible to change skin area exposed F. Position table and image receptor: X-ray tube too close to patient increases dose; high image receptor increases scatter G. Keep patient and operator body parts out of field of view H. Maximize shielding and distance from X-ray source for all personnel I. Manage and monitor dose in real time from beginning of case
III. Post Procedure

A. Document radiation dose in records (fluoroscopy time, $K_{a,r}$, P_{KA})
B. Notify patient and referring physician when high dose delivered
    1. $K_{a,r}$ >5 Gray, chart document; inform patient; arrange follow up
    2. $K_{a,r}$ >10 Gray, qualified physicist should calculate skin dose
    3. PSD >15 Gray, Joint Commission sentinel event
C. Assess and refer adverse skin effects to appropriate consultant

DAP, dose are product; $K_{a,r}$, total air kerma at reference point; P_{KA}, air kerma area product; PSD, peak skin dose.

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