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REVIEW /*Interventional imaging*

Recognition and management of dermatologic complications from interventional radiology procedures

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KEYWORDS
Skin;
Radiation dermatitis;
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Abstract A variety of dermatologic complications can occur after interventional radiology procedures, including fluoroscopy-induced radiation dermatitis, thermal skin injury from tumor ablation, non-target embolization to the skin, allergic reactions related to interventional radiology procedures, and dermatitis and infections at catheter sites. Yet, interventional radiologists typically lack training in dermatology. This review focuses on recognition of dermatologic complications and introduces basic principles for management of these complications. By taking a more active role in the diagnosis, management, and follow-up of dermatologic complications, interventional radiologists can improve the care for patients suffering iatrogenic skin inury.
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Dermatologic complications, such as radiation-induced dermatitis [1], thermal injury burns [2—4], ischemia leading to necrosis [5—7], allergic reactions [8,9], and superficial infections [10], are relatively uncommon after interventional radiology procedures with incidences ranging from 0.0001 to 2% [9—13]. However, given the large number of image guided procedures performed, with estimates of 377 million diagnostic and interventional radiologic examinations per year in the USA [14], interventional radiologists are likely to encounter these uncommon complications throughout their careers. Although interventional radiologists lack formal training on dermatologic disorders, they play an important role in helping recognize and guide management of dermatologic complications alongside non-interventional radiologists who are unfamiliar with the procedural details.

The purpose of this review was to focus on radiation-induced dermatitis, thermal injury from percutaneous

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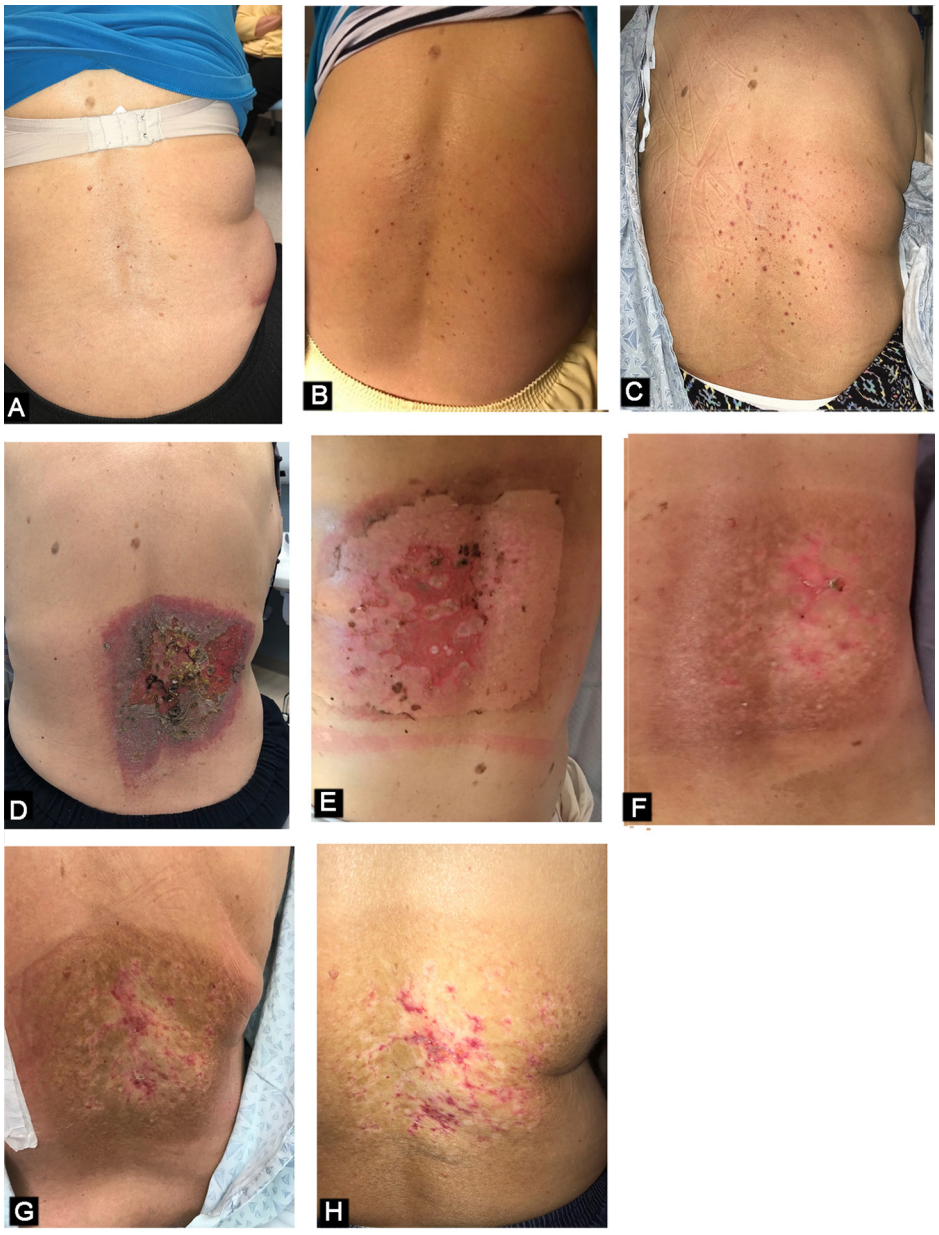

Figure 1. A 59-year-old woman with acute on chronic portal and superior mesenteric vein thrombosis and acute venous mesenteric ischemia underwent a complex procedure involving portal vein recanalization, superior mesenteric vein thrombectomy, transjugular intrahepatic portosystemic shunt insertion, and esophageal variceal embolization with an estimated 16 Gy dose the skin. A. At 10 days, there is no evidence of skin abnormalities, other than residual flank ecchymosis related to the transhepatic puncture. B. At 3 weeks post-procedure, she developed asymptomatic erythematous papules on her right mid lower back. C. At 1 month, she developed a geographically demarcated rectangle of erythema, with increased erythematous papules, which was mildly painful and pruritic. At this time, she was advised to apply 1% hydrocortisone and moisturizer. D. Over the subsequent few weeks, the erythema became pronounced and very painful, with development of wet desquamation. Wound cultures were positive for staphylococcus aureus, for which cephalexin 500 mg was prescribed. An Allevyn dressing (Smith & Nephew) was placed and instructed to keep in place for 5—7 days. Once the dressing was removed, the patient kept the skin clean with water. She applied mupirocin ointment over the ulcerated area and Vaseline to the rest of the wound. Non-stick gauze were placed over the entire area and kept in place with paper tape. E. Ten days later, at 2 months post-procedure, substantial wound healing had occurred. She was instructed to do this daily until the skin has healed. At her follow-up visit 12 days later, the wound had significantly improved. F-H. At 3, 4, and 7 months post-procedure, the wet desquamation had resolved, with residual hyperpigmentation and areas of residual erythema and incomplete epithelization and continued pain with contact to the area.

ablation, non-target embolization to the skin, allergic drug reactions, superficial skin infections, and miscellaneous cutaneous disorders. Emphasis is placed on the standard of care of skin treatment through barrier protection, early recognition of super-infection, and distinguishing simple contact dermatitis from other entities.

Fluoroscopy-induced radiation dermatitis

The radiobiology of fluoroscopy-induced radiation dermatitis (FIRD) has been reviewed elsewhere [1]. The extent of radiation-induced skin changes directly correlates with exposure dose and ranges from early transient ischemia

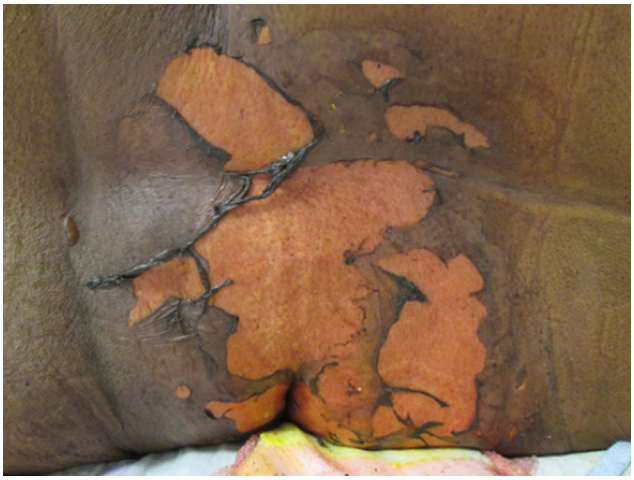

Figure 2. A 68-year-old woman with pancreatic cancer underwent pancreatico-duodenectomy with multiple complications requiring nine separate fluoroscopy-guided interventional radiology procedures, including biliary drainage catheter insertion, and repeated complex and lengthy endovascular procedures to address gastroduodenal artery hemorrhage, resulting in a cumulative skin dose of 12 Gy at the right lower back over the course of 6 weeks. Two months after the procedure the patient was found to have a rectangular shaped area of partial-thickness skin loss and sloughing of devitalized skin on the right mid back and several areas sloughing devitalized skin, compatible with dry desquamation due to cumulative radiation exposure.

(2 Gy), permanent erythema (7 Gy), telangiectasias (12 Gy), dermal necrosis (18 Gy), and secondary ulceration (20 Gy). FIRD usually occurs after exposure to radiation doses of 10 Gy or higher [12,15]. Tracking of fluoroscopy skin dose metrics, such as dose area product and air kerma, and reporting FIRD as adverse events are important improvement activities and are increasingly required by hospital accrediting entities.

Risks of FIRD can be minimized through careful attention to imaging technique including reducing the duration of exposure, fluoroscopy dose, and pulse rate, and by maximizing the distance from the source to the skin, beam collimation, time interval between exposures, and variation in angulation. Although many of these factors are under operator control, susceptibility to FIRD also depends on host factors such as light skin color, smoking, body constitution, obesity, overlapping skin folds, compromised skin integrity, poor nutritional status, autoimmune diseases including connective tissue diseases, diabetes mellitus, and hyperthyroidism, defects in DNA repair genes and chemotherapeutic agents [16,17].

Immediate FIRD, occurring within a few days of exposure, is uncommon after fluoroscopically-guided procedures [1]. Acute FIRD usually occurs within 90 days of radiation exposure, typically simulating a burn injury that varies from erythema, dry to moist desquamation, blistering, ulceration, or necrosis (Figs. 1 and 2). Subacute FIRD occurs weeks to months after exposure and shows features overlapping with acute and chronic FIRD. Chronic FIRD occurs months to years after exposure. It may occur in the absence of any acute damage or after a variable latent period following acute changes and typically features permanent erythema and telangiectasias, skin fragility, ulceration, loss of follicular structures, late-onset dermal necrosis, and secondary cutaneous malignancies [12,16]. Chronic FIRD is usually permanent, progressive, and potentially irreversible [16].

The key to diagnosis of FIRD is recognition that the skin injury may manifest weeks to months after the exposure and that the injury occurs in a characteristic location, at the site of beam entry, which is typically on the patient's back. The clinical appearance of fluoroscopy related radiation injury is unique, and the rectangular shape and mixed surface changes are important diagnostic clues [18].

In patients lost to interventional radiology follow-up the diagnosis may be unclear, prompting a biopsy and histopathological examination. Histologically-confirmed FIRD reveals ulceration, prominent telangiectasias, atypical stellate fibroblasts, epidermal atrophy, and absence of inflammation [12]. Many institutions, including ours, have implemented policies to warn patients regarding the risk of skin burns after high-dose procedures and to ensure follow-up in the interventional radiology clinic [15], helping aid in the correct diagnosis and avoid unnecessary skin biopsies.

Treatment of FIRD is based on the wound care literature and is not specific to this entity. Evidence shows that radiation dermatitis heals more rapidly with the use of dressings that provide a moist healing environment which enhances re-epithelialization, lyses necrotic tissue, and encourages phagocytosis of necrotic debris and bacteria [19]. Hydrogel and hydrocolloid dressings are two dressing types that can provide such an environment. Petrolatum-based emollients are commonly used, with or without hydrogel dressings [20].

The use of corticosteroids is controversial and has shown mixed results [17]. Chronic ulcers and skin necrosis require multidisciplinary care. Severe cases of skin necrosis and ulceration may require debridement and skin grafting [17]. Telangiectasia is a form of chronic radiation dermatitis that may be psychologically distressing for patients given its physical disfiguration. Pulsed dye laser treatment has been beneficial in clearing radiation-induced telangiectasias [20]. In patients with FIRD, close follow-up is essential to monitor for progression and malignant transformation into squamous cell carcinoma or basal cell carcinoma [12].

Thermal skin injury from tumor ablation

Percutaneous thermal ablation techniques are widely used for treatment of benign and malignant tumors. There are 2 main categories: those that destroy the tissue with heat (radiofrequency, laser, and microwave ablation) and those that destroy the tissue by freezing (cryoablation) [2,21]. One of the most common complications is the unintended thermal damage to nearby healthy structures, including painful skin burns (Fig. 3) and frost-nip/bite (Fig. 4) [2].

There are varieties of techniques that can be used to prevent thermal injury during tumor ablation [2]. To prevent injury of non-dermal structures, thermal applicators should be directed towards, rather than alongside, the vulnerable structure given the limited and generally predictable forward extent of thermal injury produced by standard commercial ablation applicators [22]. To prevent skin injury, a long trajectory for the applicator with a remote skin entry site relative to the tumor may prevent the ablation zone

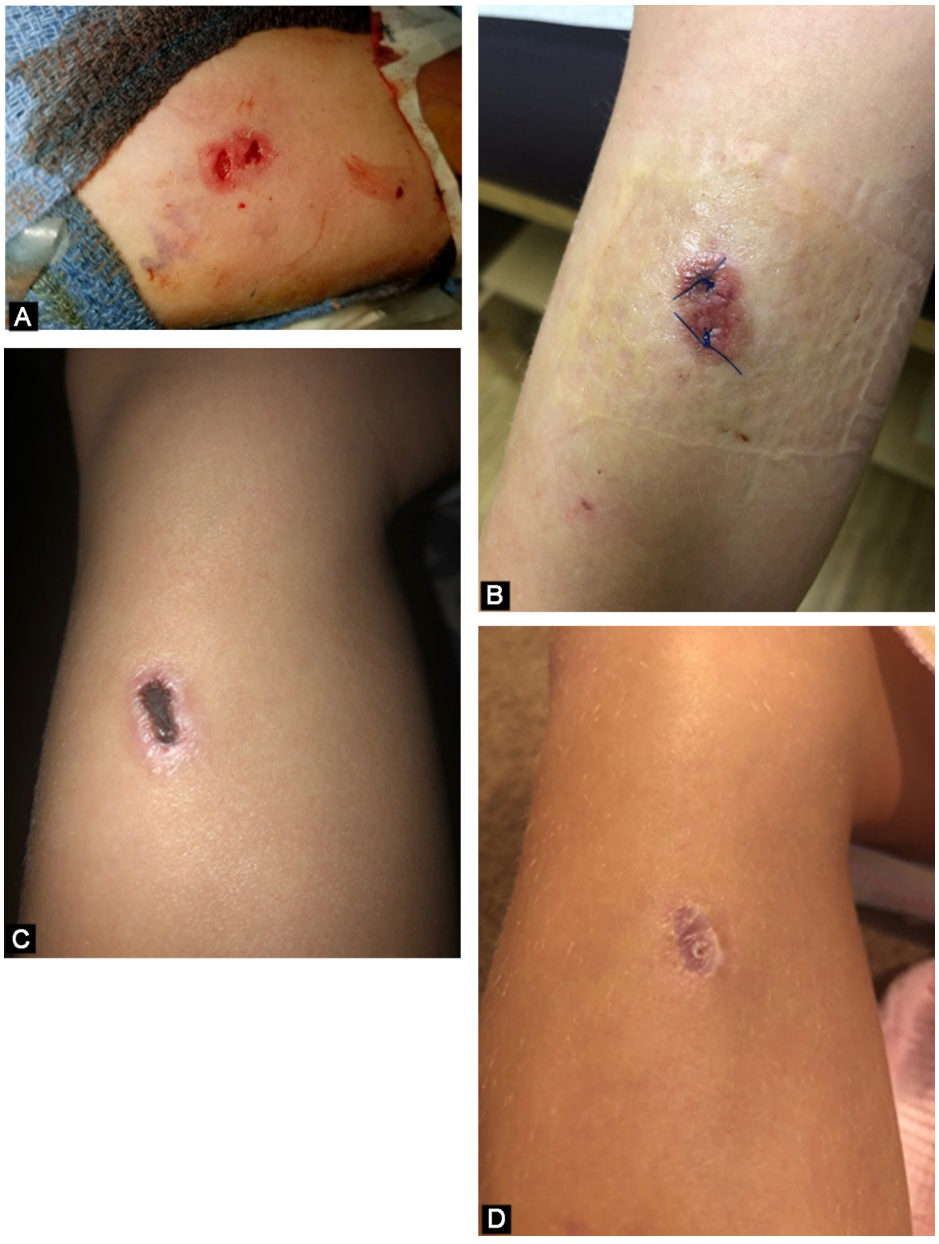

Figure 3. A 6-year-old child with an osteoid osteoma of the tibia only a few millimeters from the skin was treated by percutaneous cryoablation. Generous injection of saline, as well as extra insulation of the probes with a 6.3 French polyurethane catheter were undertaken to minimize thermal injury to the skin. A. Upon completion of the case, there was a well demarcated 3 mm rim of erythema around the two probe entry sites, which was deemed highly suspicious for thermal injury. Because the incisions were gaping, simple interrupted nylon sutures were used to approximate the skin edges and bacitracin was applied. B. Over the next week, the erythema persisted, appearing somewhat indurated. The sutures were removed after 7 days. C. Over the subsequent month, the site became less erythematous with development of central ulceration that filled in with eschar. D. Healing via secondary intention occurred over the subsequent month, after which the eschar had resolved.

from propagating to the skin surface. Fluid or gas can be used to displace the target tumor from surrounding structures to insulate organs vulnerable to thermal injury. Subdermal fluid injection (or 10—20 ml of lidocaine 1%) offers analgesia as well as skin insulation by displacing the ablated zone away from the skin [2]. Heat packs or sterile surgical gloves filled with warm water can be placed around the cryoprobes on the patient's skin throughout the ablation time to protect the skin from freezing [2]. Management of burns in an outpatient setting includes analgesia, assessment of size and depth of wound, confirming updated tetanus immunization, and plan for re-evaluation in 24 to 48 hours following injury [23].

The early treatment of burns centers on moist wound healing to help decrease cellular dehydration and promote re-epithelialization [24]. These environments can be created using topical agents or use of occlusive dressings. Superficial burns heal within a week and may only require topical hydrating lotions or aloe vera for treatment. These minor wounds often only require topical antibiotics

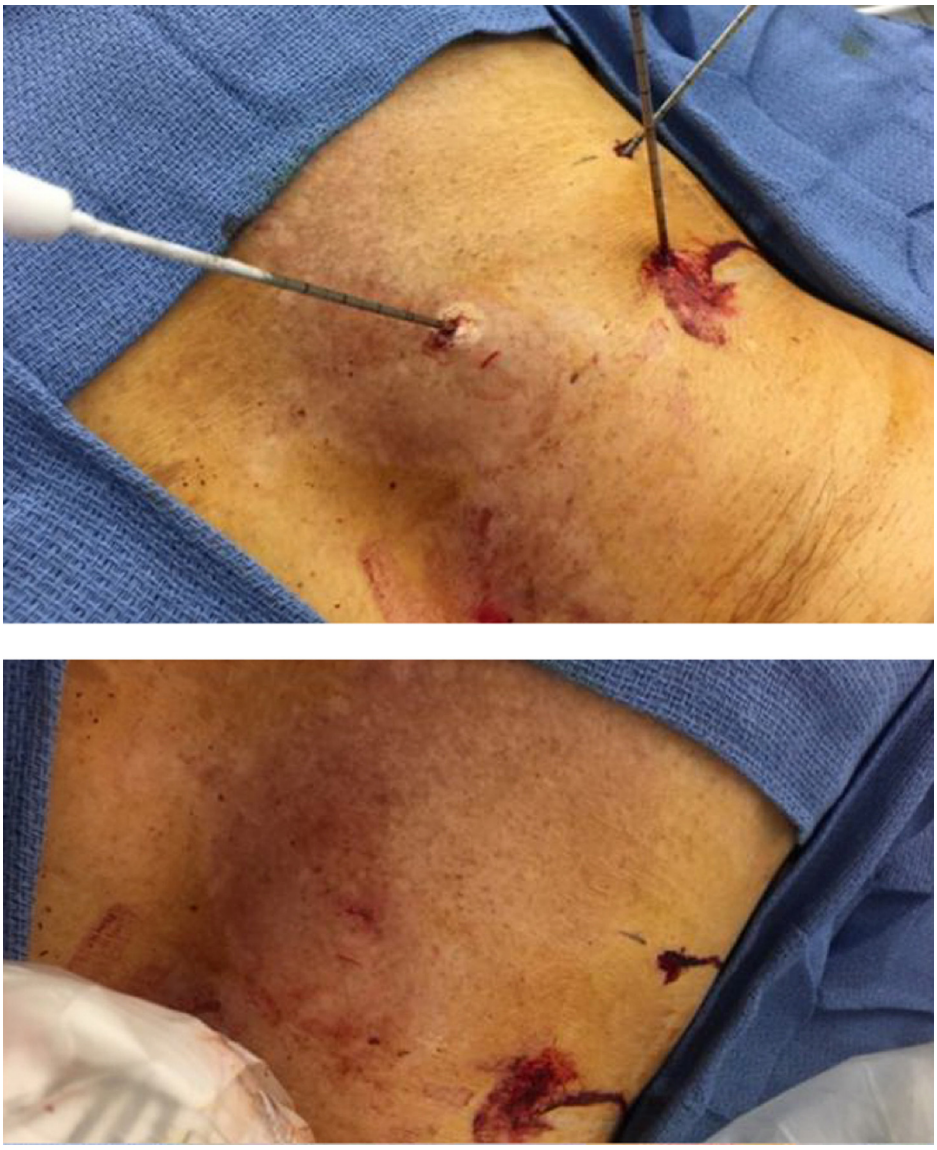

Figure 4. A 74-year-old man underwent cryoablation for renal cell carcinoma and during cryoablation freezing of the skin was noticed. A heat pack was applied at the base of the needle and treatment was continued. There were no sequelae due to prompt re-warming of this frost-nip injury.

if there is concern for a contaminated wound. Superficial partial-thickness and deep partial-thickness wounds require longer healing times and are often dressed with topical antibacterials or topical antimicrobial-containing substances such as silver sulfadiazine. Newer biosynthetic dressings, silver-containing dressings, and silicon-coated dressings have showed some advantages compared with silver sulfadiazine and their use should be considered. There is no role for systemic prophylactic antibiotics in patients with burns [24].

Fundamental therapeutic goals in frostbite are rapid re-warming, prevention of further cold exposure, and restoration of circulation. Triple-phase bone scans are considered the standard of care for assessing tissue viability during the initial days following injury. Once the patient is in a setting in which re-freezing cannot occur, rapid water bath re-warming is indicated. The water bath temperature should be about 37—39 °C (99—102 °F) [8]. Affected skin should not be rubbed dry as abrasion can cause more tissue trauma; instead, the affected skin should be allowed to air dry. Significant edema is expected after frostbitten areas have been thawed. Topical aloe vera cream/gel (an antiprostaglandin) should be applied to thawed tissue under a loose dressing [25]. Superficial white (non-hemorrhagic) bullae may be debrided to avoid prolonged exposure to prostaglandins and thromboxanes in blister fluid. Pentoxifylline has been found to be useful, as have anti-inflammatory agents such as methylprednisolone, methimazole and aspirin [8].

For patients with thermal injury, we recommend advising the patient to follow a basic wound care regiment: cleanse area gently with soap daily in the shower, pat dry with clean towel, apply a liberal amount of Vaseline, apply bandage to keep Vaseline in place. The patient should be alerted to signs and symptoms of infection. If there is a non-healing ulcer, we recommend referral to dermatology or wound care specialist.

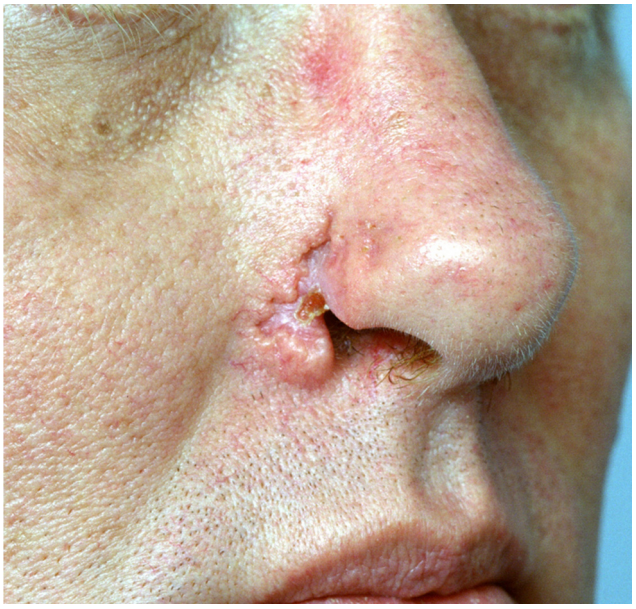

Figure 5. A 40-year-old man with refractory epistaxis underwent embolization of the sphenopalatine artery, a branch of the internal maxillary. For the embolization 45—150 um polyvinyl alcohol particles were used resulting in ischemia and necrosis of the nose. Surgical reconstruction was required.

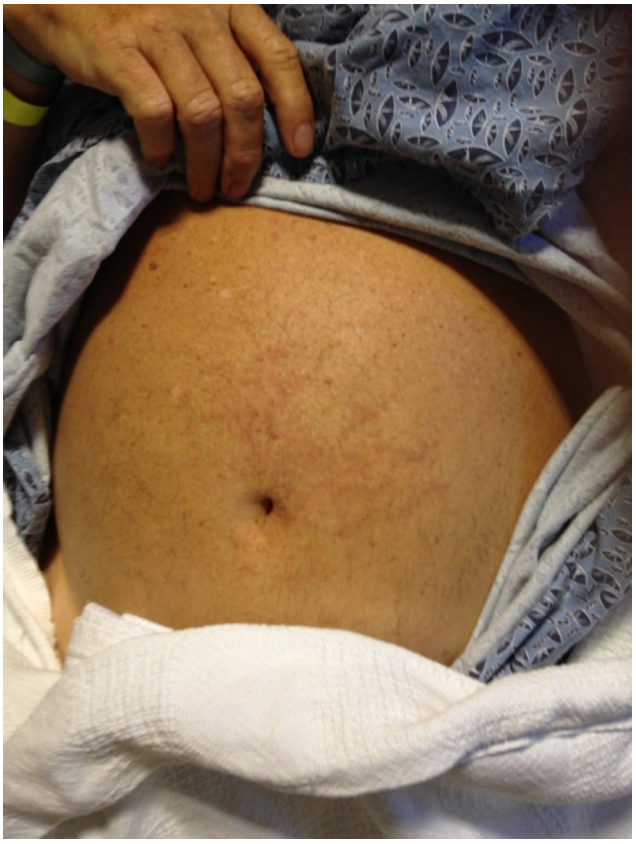

Figure 6. A 59-year-old man underwent bland particle embolization of a hepatocellular carcinoma located in segment 4 of the liver. On post-procedure day 1, the patient developed a mildly sensitive periumbilical rash. Retrospectively, a subtle falciform artery was identified within the treated arterial distribution. At his follow-up appointment 2 weeks later, the rash had resolved.

Non-target embolization to the skin

Skin injury can occur from non-target embolization of embolic agents when treating tumors [26] or hemorrhage, or plaque atheroembolization during peripheral arterial disease intervention.

Two factors that have been shown to cause a higher incidence of skin injury after transcatheter therapy are smaller size of embolization agents and use of continuous arterial injection [27]. Small particles cause distal embolization beyond small arteriolar anastomoses and increase risk of organ injury (Fig. 5). Slow and cautious infusion of embolic material will minimize reflux into adjacent vessels therefore minimizing the effect to surrounding organs [28], including the skin. Additionally, knowledge of variant arterial anatomy is important to avoiding non-target embolization (Fig. 6) [28,29]. Non-target sclerotherapy to the skin during treatment of vascular malformations can cause severe skin necrosis [30]. The diagnosis of non-target embolization to the skin is usually immediately suspected based on the procedure history. However, if biopsied, pathology will show dermal sclerosis with fat necrosis and foreign body reaction, consistent with extravasation of chemotherapeutic agent [31].

The abrupt onset of distal livedo reticularis, especially after an endovascular procedure, should prompt consideration of cholesterol emboli, which involves dislodgment of cholesterol crystals to circulation following rupture of atherosclerotic plaque. This leads to embolization of peripheral arterioles with diameters of 100—200 μm [32], usually involving the extremities, but potentially also the abdominal wall. The cutaneous findings of cholesterol emboli include livedo reticularis (49%), multiple sites of peripheral gangrene (35%), cyanosis (28%), ulceration (17%), nodules (10%) and purpura (9%) [8]. Retiform purpura, especially when it occurs distally together with more extensive distal livedo reticularis, is especially suggestive of this diagnosis [8]. Histopathological analysis of tissue samples obtained from skin biopsy provides definitive diagnosis [33]. Skin findings may be accompanied by laboratory markers of systemic inflammation such as leukocytosis, high erythrocyte sedimentation rate, and elevated levels of C reactive protein, hypocomplementemia, anemia, thrombocytopenia, hypereosinophilia, eosinophiluria, and renal failure [33].

Due to its rarity, there is no consensus regarding treatment of non-target particle embolization to the skin. It is mostly treated with local cold or warm compresses, non-steroidal anti-inflammatory drugs (NSAIDs), topical agents such as silver sulfadiazine, and intralesional or oral steroids with or without antihistamines. Surgical excision may be necessary if chronic skin ulceration and eschar develop, which is suggestive of tissue necrosis [27,34]. Pentoxifylline, which is known to improve microcirculatory perfusion, has also been successfully used to treat the skin rash after transarterial chemoembolization (TACE) [27,34]. Topical application of ice packs can be used to vasoconstrict superficial arterial branches when the skin is susceptible to non-target deposition of chemoembolic agents and may

provide an additional measure of safety in the prevention of cutaneous complications from heat [35].

Current literature for cholesterol emboli management recommends supportive treatment and aggressive control of risk factors, (e.g., statin therapy, antiplatelet therapy, and avoidance of further vascular instrumentation) [6]. Arterial ulcers can benefit from restoration of peripheral arterial blood flow, either by surgical or endovascular treatment. In principle, local treatment of arterial ulcers is similar to that of other types of skin ulcers, with two major exceptions: 1. Sharp debridement should be performed very cautiously or avoided in order to prevent further necrosis and ulcer enlargement; and 2. Vacuum assisted closure therapy should be avoided as it can lead to worsening of the ulcer [8]. While most studies support it, corticosteroid treatment of cholesterol emboli is controversial. Successful treatment of skin necrosis with iloprost, a prostacyclin analogue, as well as hyperbaric oxygen and pentoxifylline, has been reported [5]. Anticoagulation is not advised, unless supported by another indication, since it may actually precipitate further cholesterol embolization [36].

Allergic reactions related to interventional radiology procedures

Drug hypersensitivity reactions can present as a morbilliform or urticarial rash (Fig. 7). Some of these reactions are predictable given their relationship to the dose and/or the pharmacologic properties of the drug [8]. In regards to hypersensitivity reactions, recent studies from the United States cited antibiotics as the most common identifiable cause, whereas most European countries identified neuromuscular blocking agents (NMBAs) as the most likely cause. A recent retrospective study found that induction agents were the most common cause of perioperative hypersensitivity reactions [9].

The most common medications administered during interventional radiology (IR) procedures include intravascular iodinated contrast material, an intravenous (IV)sedative (narcotic and benzodiazepine), a prophylactic antibiotic, and anticoagulation (heparin and tissue plasminogen activator or TPA). Allergic reactions to intravascular iodinated contrast material are reviewed elsewhere [37,38]. The most common reactions involve cell-mediated hypersensitivity with clinical manifestations of erythematous plaques and occasionally maculopapular exanthems [39].

Only a small fraction of drug eruptions are life-threatening or lead to disabling sequelae. The most important clues for diagnosing anaphylaxis are clinical presentations such as skin and mucosal involvement, respiratory symptoms, and cardiovascular dysfunction [40]. Immediate discontinuation of the drug, airway support with 100% oxygen, and early administration of epinephrine are the cornerstones of treatment [41].

Because of the potential risk involved, provocation tests should be performed only in centers with experience in performing and monitoring these tests, and in immediate emergency treatment [37]. Re-challenge of the drug carries the risk of inducing a more severe reaction, thus limiting its use for both ethical and medico-legal reasons.

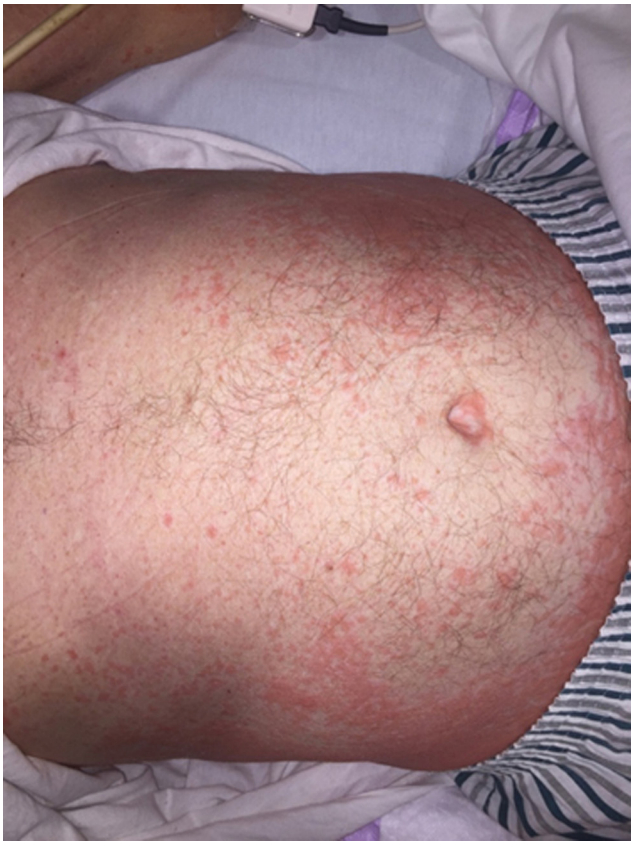

Figure 7. A 42-year-old man underwent thrombolysis for acute lower extremity deep venous thrombosis. Fentanyl and midazolam were administered for sedation, heparin and tissue plasminogen activator were given for thrombolysis, and venograms were performed using intravenous iodinated contrast material. During the procedure he developed diffuse rash thought to be an allergic reaction to iodinated contrast material.

Furthermore, the recurrence rate is not 100% with re-challenge (e.g., there are refractory periods) and a negative result may give an erroneous sense of security [8].

In regards to treatment of cutaneous symptoms, we recommend the following: For scattered, transient urticaria, give supportive treatment and observation. For scattered protracted urticaria, give intramuscular (IM) or intravenous H1 antihistamines. Lastly, for profound urticaria, consider adrenaline 1:1000, 0.1—0.3 ml (0.1—0.3 mg) IM for adults, 0.01 mg/kg IM up to 0.3 mg maximum in children [42]. If drug reactions are pruritic, topical triamcinolone 0.1% cream or ointment twice a day may provide relief.

Dermatitis and infections at catheter sites

Catheter infections are among the most common complications in IR [43—45] (Fig. 8). However, non-infectious allergic or irritant contact dermatitis is also an extremely common entity and failure to discontinue provoking irritants or allergens can lead to the worsening of exit site rash, incorrect diagnosis of infection, and potentially results in catheter removal (Fig. 9) [46].

Diagnosis of catheter site infection involves inspection of the skin and may reveal erythema, edema, warmth and

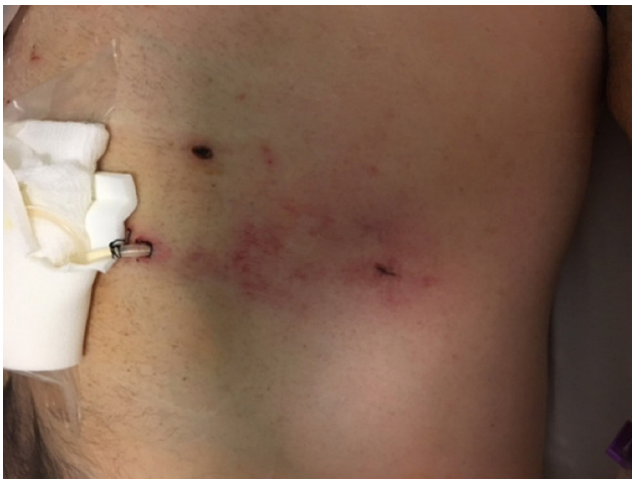

Figure 8. A 46-year-old man underwent tunneled peritoneal catheter insertion for palliation of increasing malignant ascites. Three days after placement the patient reported increasing pain associated with the catheter. On physical examination there was warmth, tenderness, and increasing erythema along the tunnel tract prompting catheter removal.

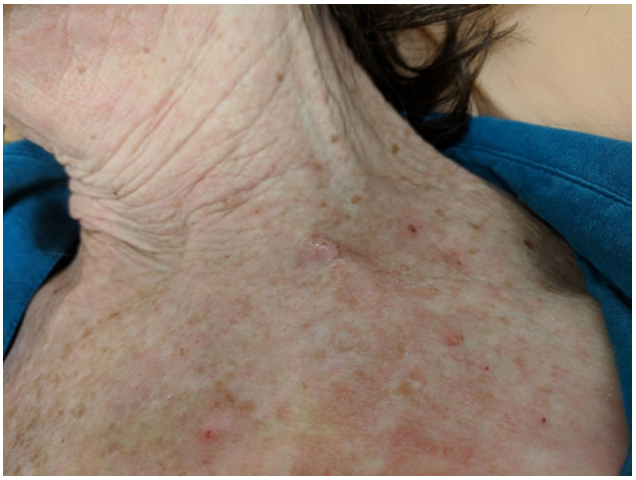

Figure 9. A 69-year-old woman developed a pruritic erythematous dermatitis 1 day after central venous port placement, extending up the neck. There was no warmth or pain and the patient denied fevers or other systemic symptoms. Given the superficial and geometric location of the dermatitis, and lack of edema, tenderness of skin, and systemic symptoms, a diagnosis of contact dermatitis was made. The patient was prescribed topical fluocinonide 0.05% ointment three times daily for one week and cetirizine as needed for symptomatic relief of itching. She was given instructions to monitor for worsening erythema, increasing warmth or pain. The rash resolved and the port was left in place.

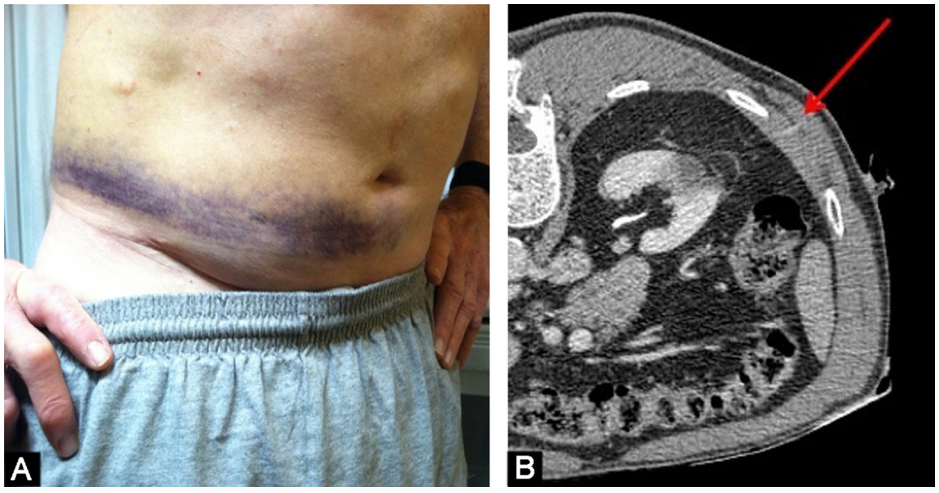

Figure 10. A 75-year-old man who underwent uneventful cryoablation of a right-sided kidney mass. A. On immediate post-procedure images, there was a small amount of asymmetric fullness within the intercostal and latissimus dorsi muscles at the probe insertion sites compatible with intramuscular blood, without significant subcutaneous blood; B. On post-procedure day 3, the patient had developed a linear ecchymosis that migrated dependently, stabilizing along his inferior abdominal wall. Usually in the setting of severe hemorrhagic pancreatitis other causes include blunt abdominal trauma, ruptured/hemorrhagic ectopic pregnancy, aortic rupture or spontaneous bleed from secondary coagulopathy.

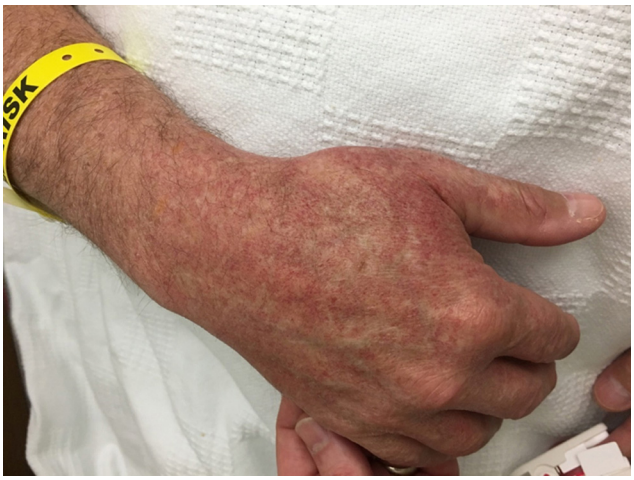

Figure 11. A 58-year-old man with cirrhosis underwent radioembolization mapping for hepatocellular carcinoma. In the recovery room after the procedure petechiae were noticed on his right hand and forearm. He was asymptomatic and there were no skin changes elsewhere. The blood pressure cuff had been placed on his right arm. This physical examination phemonenon, also known as the tourniquet test, is evidence of capillary fragility and thrombocytopenia. Risk factors for the development of this self-limited condition include diabetes mellitus, hypertension, thrombocytopenia, chronic steroid use, antiplatelets and anticoagulants.

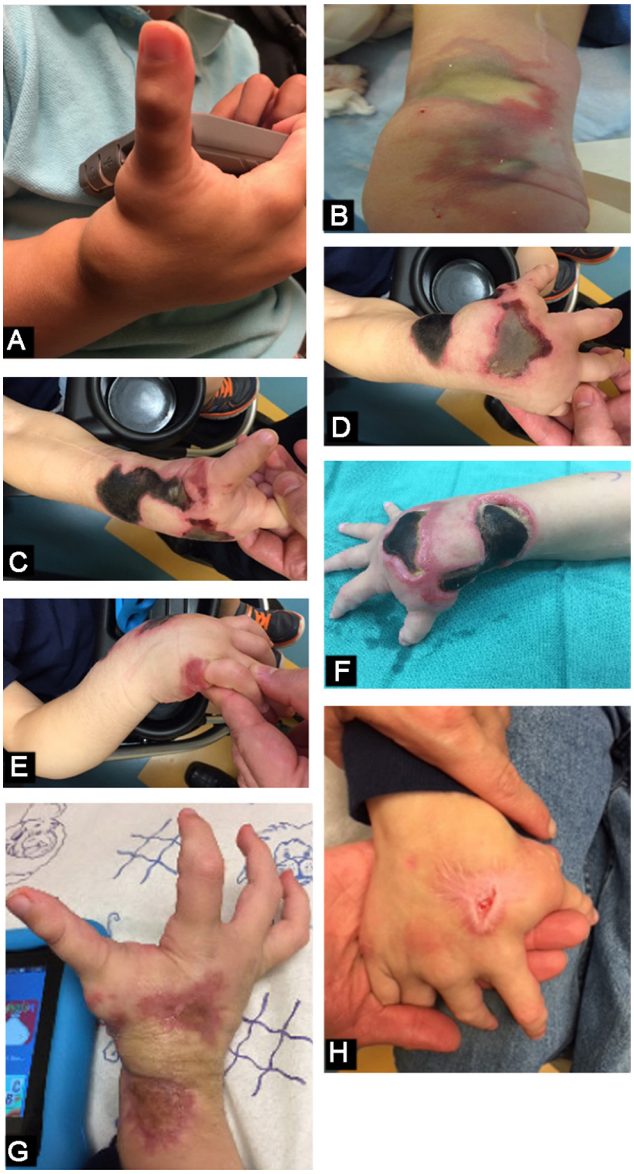

Figure 12. A 3-year-old child with a PIK3CA mutation resulting in extensive lymphatic malformations underwent percutaneous embolization of a right hand lymphatic malformation component. A. Photograph shows right hand lymphatic malformation; B-F. The lesion was treated with 120 mg sotradecol and 400 mg doxycycline used as sclerosing agents, and was complicated by skin necrosis. Initial treatment involved gentle cleansing and topical bacitracin ointment. Definitive treatment involved debridement followed by delayed (1 month) autologous skin grafting. Skin grafting was delayed because upon debridement there was residual lymphatic malformation at the wound bed; G, H. Integra (Life Sciences,), a porous matrix of cross-linked bovine tendon collagen and glycosaminoglycan, was placed on the wound to build an appropriate wound bed, and adequate time was allowed to transpire for incorporation and vascular in-growth and then patient was treated with autologous skin grafting.

pain or tenderness. Constitutional symptoms of infection will likely also be seen including fever, fatigue, chills, night sweats, bowel and bladder changes [47]. Current recommendations allow for a trial of antibiotics for 72 hours to salvage long-term catheters. If there is not relief of symptoms or for short-term catheters, catheter removal is indicated [48]. Prevention of catheter infections involves proper preparation of the skin with > 0.5% chlorhexidine and alcohol. If chlorhexidine cannot be used in a particular patient, acceptable alternatives include tincture of iodine, iodophor and 70% alcohol [10]. Patients should be told not to immerse the catheter site or catheter in water and to replace gauze dressings every 2 days or transparent dressings every 7 days. Patients should clean the site with 2% chlorhexidine wash and change the dressing if it appears soiled [10]. Currently, there is no evidence to suggest the use of antimicrobial-coated catheters such as those incorporated with silver, heparin and other antibiotics decreases the incidence of site and blood infections or mortality [49]. Additionally, the use of systemic antibiotic prophylaxis before the procedure is not known to decrease morbidity, mortality or infection risk [10].

Contact dermatitis presents with erythema, edema, vesicles, oozing, and notably intense pruritus [50] and may assume a geometric shape corresponding to the area of the offending agent. Erythema and rash around the exit site can be mistaken for exit site infection; however absence of drainage, tenderness, and swelling may be clues for contact dermatitis [46,50]. Whereas contact dermatitis appears acutely, infectious complications may occur at any time. Therefore, erythema and rash appearing around a long indwelling catheter should be viewed with a high index of suspicion for infection. The diagnosis of contact dermatitis is usually established on clinical grounds based on characteristic appearance of rash, negative cultures, and favorable response to withdrawal of suspected agent along with supportive measures such as topical steroid preparations [46]. A detailed history and clinical examination are crucial and guide patch

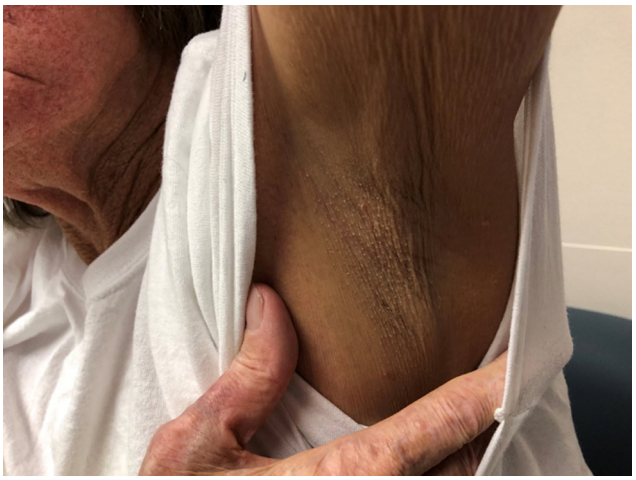

Figure 13. A 68-year-old man underwent combined bland embolization with ethiodized oil (lipiodol®) and microwave ablation for hepatocellular carcinoma. Approximately 2 months after the procedure he developed patchy hair loss on his head and complete hair loss in both axillae and both legs. Thyroid function tests and iron studies were normal. He was diagnosed with telogen effluvium, a condition in which hair follicles become synchronized in the telogen phase of the hair cycle after physiologic stress such as surgery or pregnancy, resulting in diffuse shedding of the hairs.

testing, which is the gold standard to diagnose contact dermatitis [50].

Miscellaneous

A variety of other dermatologic complications can be seen in IR ranging from localized to diffuse and from clinically insignificant to severe. Hemorrhagic complications include entities such as Grey Turner's sign [51] (Fig. 10) and Rumpel-Leede phenomenon [52] (Fig. 11). Non-target sclerotherapy to the skin during treatment of vascular malformations can cause severe skin necrosis (Fig. 12) [30]. Unusual patterns of hyperpigmentation from bleomycin sclerotherapy can also be seen and have been described elsewhere [53]. Global physiologic stress from any IR procedure can lead to unusual phenomena such as telogen effluvium, which may appear weeks or months after the procedure (Fig. 13).

Conclusion

Interventional radiologists can take a prominent role in recognizing and managing dermatologic complications. The most common dermatologic complications of IR procedures include radiation dermatitis, thermal injury from ablation, non-target embolization, allergic reactions, and catheter related infection and contact dermatitis. Although some complications appear acutely after IR procedures and may be obvious based on the immediate presentation, others, most notably radiation dermatitis, may be associated with a delayed presentation occurring up to 30 days or more after the procedure. The delayed nature of some of these complications may make the correct diagnosis less obvious to dermatologists or other physicians unfamiliar with IR procedures. Therefore, by taking a more active role in the diagnosis, management, and follow-up of dermatologic complications, interventional radiologists can improve the care for patients suffering iatrogenic skin injury.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

The authors declare that they obtained a written informed consent from the patients and/or volunteers included in the article. The authors also confirm that the personal details of the patients and/or volunteers have been removed.

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Disclosure of interest

The authors declare that they have known competing financial or personal relationships that could be viewed as influencing the work reported in this paper.

References

[1] Balter S, Hopewell JW, Miller DL, Wagner LK, Zelefsky MJ. Fluoroscopically guided interventional procedures: a review of radiation effects on patients' skin and hair. Radiology 2010;254:326—41.

[2] Tsoumakidou G, Buy X, Garnon J, Enescu J, Gangi A. Percutaneous thermal ablation: how to protect the surrounding organs. Tech Vasc Interv Radiol 2011;14:170—6.

[3] Atwell TD, Carter RE, Schmit GD, Carr CM, Boorjian SA, Curry TB, et al. Complications following 573 percutaneous renal radiofrequency and cryoablation procedures. J Vasc Interv Radiol 2012;23:48—54.
[4] Etienne A, Waynberger E, Druon J. Interstitial laser photocoagulation for the treatment of osteoid osteoma: retrospective study on 35 cases. Diagn Interv Imaging 2013;94:300—10.
[5] Aivaz O, Turegano MM, Radfar A. A purpuric patch on the flank. JAMA Dermatol 2015;151:97—8.
[6] Ghahramani GK, Seline AE, Wanat KA. Postprocedural Blue Toes. JAMA 2016;315:1396—7.
[7] Tarkan O, Surmelioglu O, Tuncer U, Akgul E. Face skin necrosis following embolization for arteriovenous malformations: a case report. Oral Maxillofac Surg 2010;14:49—52.
[8] Bolognia J, Schaffer JV, Cerroni L. Dermatology. Philadelphia: Elsevier; 2018 https://getitatduke.library.duke.edu/?sid=sersol&SS_jc=TC0001965038&title=Dermatology.
[9] Iammatteo M, Keskin T, Jerschow E. Evaluation of periprocedural hypersensitivity reactions. Ann Allergy Asthma Immunol 2017;119:349—55 [e2].
[10] O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, et al. Guidelines for the prevention of intravascular catheter-related infections. Clin Infect Dis 2011;52:162—93.
[11] Ekmekci P, Bengisun ZK, Kazbek BK, Akmansu H, Beriat GK, Suer AH. Oropharyngeal angioneurotic edema due to recombinant tissue plasminogen activator following massive pulmonary thromboembolism. Int Immunopharmacol 2011;11:1384—5.
[12] Lyons AB, Harvey VM, Gusev J. Fluoroscopy-induced chronic radiation dermatitis [FICRD] after endovascular abdominal aortic aneurysm endoleak repair. JAAD Case Rep 2015;1:403—5.
[13] Tomar GS, Tiwari AK, Chawla S, Mukherjee A, Ganguly S. Anaphylaxis related to fentanyl citrate. J Emerg Trauma Shock 2012;5:257—61.
[14] Mettler Jr FA, Bhargavan M, Faulkner K, Gilley DB, Gray JE, Ibbott GS, et al. Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources-1950-2007. Radiology 2009;253:520—31.
[15] Greffier J, Goupil J, Larbi A, Stefanovic X, Pereira F, Moliner G, et al. Assessment of patient's peak skin dose during abdominopelvic embolization using radiochromic [Gafchromic] films. Diagn Interv Imaging 2018;99:321—9.
[16] Batrani M, Kubba A, Sundharam J. Fluoroscopy-induced chronic radiation dermatitis masquerading as morphea: A diagnostic pitfall. Indian J Pathol Microbiol 2018;61:393—6.
[17] Reichman EF. Fluoroscopy-induced radiation dermatitis. J Emerg Med 2014;47:117—9.
[18] Pruitt LG, Rogers W, Byarlay JA, Googe PB. Subacute radiation dermatitis after fluoroscopy. J Cutan Pathol 2016;43:1091—5.
[19] Leventhal J, Young MR. Radiation dermatitis: recognition, prevention, and management. Oncology 2017;31:885—7.
[20] Hymes SR, Strom EA, Fife C. Radiation dermatitis: clinical presentation, pathophysiology, and treatment 2006. J Am Acad Dermatol 2006;54:28—46.
[21] Cornelis F, Balageas P, Le Bras Y, Rigou G, Boutault JR, Bouzgarrou M, et al. Radiologically-guided thermal ablation of renal tumours. Diagn Interv Imaging 2012;93:246—61.
[22] Kurup AN, Schmit GD, Morris JM, Atwell TD, Schmitz JJ, Weisbrod AJ, et al. Avoiding complications in bone and soft tissue ablation. Cardiovasc Intervent Radiol 2017;40:166—76.
[23] Laskowski-Jones L, Jones LJ. Frostbite: don't be left out in the cold. Nursing 2018;48:26—33.
[24] Monseau AJ, Reed ZM, Langley KJ, Onks C. Sunburn, thermal, and chemical injuries to the skin. Prim Care 2015;42:591—605.
[25] Handford C, Thomas O, Imray CHE. Frostbite. Emerg Med Clin North Am 2017;35:281—99.
[26] Djaber S, Bohelay G, Moussa N, Dean C, Del Giudicce C, Sapoval M, et al. Cutaneous necrosis after embolization of spontaneous soft-tissue hematoma of the abdominal wall. Diagn Interv Imaging 2018;99:831—3.
[27] Nagpal P, Bhalala M, Vidholia A, Sao R, Sharma N, Mehta D, et al. Abdominal skin rash after TACE due to non-target embolization of hepatic falciform artery. ACG Case Rep J 2016;3:217—20.
[28] Ingraham CR, Johnson GE, Nair AV, Padia SA. Nontarget embolization complicating transarterial chemoembolization in a patient with hepatocellular carcinoma. Semin Intervent Radiol 2011;28:202—6.
[29] Stalder G, Deplanque G, Shabafrouz K, Orcurto A, Bize P, Duran R, et al. Dexrazoxane prevents skin necrosis in non-target embolization of falciform artery during transcatheter arterial chemoembolization [TACE]. Diagn Interv Imaging 2018;99:179—80.
[30] Horbach SE, Lokhorst MM, Saeed P, de Gouyon Matignon de Pontouraude CM, Rothova A, van der Horst CM. Sclerotherapy for low-flow vascular malformations of the head and neck: a systematic review of sclerosing agents. J Plast Reconstr Aesthet Surg 2016;69:295—304.
[31] Baysal T, D'Agostino HB, Serra EE, Valji K, Rose SC, Kinney TB. Supraumbilical dermal sclerosis and fat necrosis from chemoembolization of hepatocellular carcinoma. J Vasc Interv Radiol 1998;9:645—7.
[32] Dizman N, Aydin Bahat K, Ozkanli S, Ozkok A. Cholesterol embolization syndrome: a report of two cases. Turk Kardiyol Dern Ars 2016;44:251—5.
[33] Agrawal A, Ziccardi MR, Witzke C, Palacios I, Rangaswami J. Cholesterol embolization syndrome: An under-recognized entity in cardiovascular interventions. J Interv Cardiol 2018;31:407—15.
[34] Jang MS, Baek JW, Kang DY, Kang JS, Suh KS, Kim ST. Supraumbilical skin rash after transcatheter arterial chemoembolization: successful treatment with pentoxifylline. J Dermatol 2011;38:1188—91.
[35] Wang DS, Louie JD, Kothary N, Shah RP, Sze DY. Prophylactic topically applied ice to prevent cutaneous complications of nontarget chemoembolization and radioembolization. J Vasc Interv Radiol 2013;24:596—600.
[36] Lyaker MR, Tulman DB, Dimitrova GT, Pin RH, Papadimos TJ. Arterial embolism. Int Crit Illn Inj Sci 2013;3:77—87.
[37] Brockow K, Sanchez-Borges M. Hypersensitivity to contrast media and dyes. Immunol Allergy Clin North Am 2014;34:547—64.
[38] Shin JG, Hwang JH, Lee BS, Park HJ, Lee SH, Lee JN, et al. A case of midazolam anaphylaxis. Clin Endosc 2014;47:262—5.
[39] Leguisamo S, Prados Castano M, Pinero Saavedra M, Cimbollek S. Recurrent anaphylaxis due to enoxaparin. J Investig Allergol Clin Immunol 2015;25:297—9.
[40] Kim KN, Kim DW, Sin YH, Lee SK. Anaphylactic shock caused by intramuscular injection of midazolam during the perioperative period: a case report. Korean J Anesthesiol 2016;69:510—3.
[41] Shrivastava S. An experience with midazolam anaphylactoid reaction. J Anesth 2012;26:642—3.
[42] Meth MJ, Maibach HI. Current understanding of contrast media reactions and implications for clinical management. Drug Saf 2006;29:133—41.
[43] Mellouk Aid K, Tchala Vignon Zomahoun H, Soulaymani A, Lebascle K, Silvera S, Astagneau P, et al. Mortality and infectious complications of therapeutic endovascular interventional radiology: a systematic and meta-analysis protocol. Syst Rev 2017;6:89.
[44] Napalkov P, Felici DM, Chu LK, Jacobs JR, Begelman SM. Incidence of catheter-related complications in patients with central venous or hemodialysis catheters: a health care claims database analysis. BMC Cardiovasc Disord 2013;13:86.
[45] Delarbre B, Dabadie A, Stremler-Lebel N, Jolibert M, Cassagneau P, Lebel S, et al. Introduction of the use of a pediatric

PICC line in a French university hospital: review of the first 91 procedures. Diagn Interv Imaging 2014;95:277—81.
[46] Gosmanova EO, Ezumba I, Fisher KR, Cleveland KO. A case report of rash at peritoneal dialysis exit site. J Investig Med High Impact Case Rep 2015;3 [2324709615618222].
[47] Ki V, Rotstein C. Bacterial skin and soft tissue infections in adults: a review of their epidemiology, pathogenesis, diagnosis, treatment and site of care. Can J Infect Dis Med Microbiol 2008;19:173—84.
[48] Mermel LA, Allon M, Bouza E, Craven DE, Flynn P, O'Grady NP, et al. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 Update by the Infectious Diseases Society of America. Clin Infect Dis 2009;49:1—45.
[49] Soi V, Moore CL, Kumbar L, Yee J. Prevention of catheter-related bloodstream infections in patients on hemodialysis: challenges and management strategies. Int J Nephrol Renovasc Dis 2016;9:95—103.
[50] Kostner L, Anzengruber F, Guillod C, Recher M, Schmid-Grendelmeier P, Navarini AA. Allergic contact dermatitis. Immunol Allergy Clin North Am 2017;37:141—52.
[51] Mookadam F, Cikes M. Images in clinical medicine. Cullen's and Turner's signs. N Engl J Med 2005;353:1386.
[52] Nguyen TA, Garcia D, Wang AS, Friedlander SF, Krakowski AC. Rumpel-Leede phenomenon associated with tourniquet-like forces of baby carriers in otherwise healthy infants: baby carrier purpura. JAMA Dermatol 2016;152:728—30.
[53] Milbar HC, Jeon H, Ward MA, Mitchell SE, Weiss CR, Cohen BA. Hyperpigmentation after foamed bleomycin sclerotherapy for vascular malformations. J Vasc Interv Radiol 2019, http://dx.doi.org/10.1016/j.jvir.2018.10.007.