

ARTICULATED RADIATION SHIELDING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application cites the priority of U.S. Provisional Patent Application No. 62/803,261, filed on 8 February 2019 (pending), and the entire contents of which are incorporated herein by reference.

BACKGROUND

FIELD

The present disclosure relates generally to radiation protection devices, and specifically to devices to protect medical personnel from radiological hazards in the operating room.

BACKGROUND

Recent improvements in electronics and robotics have enabled surgeons to use noninvasive microsurgical techniques to replace numerous open incision techniques. When the site of surgical intervention is not open to the operating room, the site must still be visualized in order to adequately guide and control the instruments. This can be accomplished by radiological monitoring, the most common example of which is X-ray monitoring. During the procedure an X-ray generator is positioned on one side of the patient to emit X-rays to the surgical site (this is generally below the patient, although the position of the X-ray generator can be varied as necessary). An X-ray intensifier is positioned to receive the emitted X-rays after they have passed through the surgical site, to convey image data to a monitor or other means to present a visual image to the surgeon.

Although these microsurgical techniques represent a vast improvement over previous open body techniques in terms of trauma to the patient, recovery time, and risk of infection, the constant radiological monitoring exposes everyone involved to more radiation than was required using the old techniques. This is a minor concern for the patient, who is likely to undergo only a small number of such surgeries in a lifetime. However, the professional medical staff who perform these procedures have much more frequent exposure, and the cumulative exposure could easily exceed safe limits unless the staff are somehow protected.

Previous attempts to solve these problems have serious limitations. Placing heavy shielding around the patient can block the radiation from reaching the medical staff. However, the medical staff still need access to the patient's body, so complete shielding is impractical; because the human body is transparent to X-rays ("radiolucent"), X-rays can shine through the patient's body and expose the medical staff. Any surgery carries with it a risk of life-threatening complications that would require the medical staff to have immediate access to the patient's body. Heavy shields around the patient's body are bulky and difficult to move, which can prevent emergency access by the medical staff to the patient in such a situation.

Another attempt to protect medical staff during such procedures has involved worn shielding, or basically radiation "armor." These have taken the form of lead vests, lead skirts, lead thyroid collars, leaded acrylic face shields, leaded acrylic glasses, and "zero gravity" leaded suits. Radiation armor has a serious disadvantage: it must be of significant mass to block X-rays (generally containing lead, a very dense metal), and it is heavy to wear. Wearing heavy radiation armor rapidly fatigues even a physically fit wearer, and with chronic use can cause orthopedic disorders. When using radiation armor to protect medical staff from X-rays, one health hazard is simply being exchanged for another.

Glasses and face shields by themselves might be of a manageable weight, but alone they protect only a tiny portion of the body.

"Zero gravity" suits are leaded body suits that are suspended by a rigid metal frame. The frame is mounted on some supporting structure, such as the floor or ceiling. As a result, the wearer does not support the suit with his or her body. This type of suspended armor has additional drawbacks. It leaves the wearer's hands and lower arms uncovered and unprotected to allow the wearer to engage in fine manual work. It limits the wearer's range of bodily movement to movements that can be accommodated by the frame, often preventing the wearer from bending over or sitting. They use a static face shield that prevents the wearer from bringing anything close to the face, for example for visual scrutiny. Suspended armor systems are extremely expensive due to their complexity and due to material costs, currently costing about \$70,000 per suit.

Another form of radiation armor is the mobile "cabin," that is a radiopaque box on wheels in which the user stands. The user is able to push the cabin from place to place while inside. The cabin has arm ports at a certain height and a visually transparent portion at a certain height. As a result, the user's hands and face cannot be repositioned or reoriented much, for example to stand or lean over. It also uses a static face shield that prevents the wearer from bringing anything close to the face, for example for visual scrutiny.

There is therefore a need in the art for a means to shield medical staff from X-rays to which a patient must be exposed that does not encumber the user's body, allows access to the patient's body, and can be rapidly reconfigured if necessary.

SUMMARY

The present disclosure describes a radiation shield assembly that addresses the problems described above by interposing a barrier between an operating area and an area containing medical personnel. Working in conjunction with the shield curtain hanging below the operating table, the shield assembly significantly reduces the radiation that reaches the personnel area both directly from the radiation generator and indirectly through the patient's radiolucent body, allows access to the patient's body, allows complete freedom of movement on the part of the user, and can be easily reconfigured as needed. The shield assembly generally comprises two shield structures supported by a support member such as a mast or suspension arm. Each shield structure has at least one generally vertical shield, and the two vertical shields can be rotated relative to one another about the longitudinal axis of the support member and translated relative to one another about the longitudinal axis of the support member.

In a first aspect a radiation shield assembly is provided, configured to block radiation emanating from a radiation source. In the first aspect the assembly comprises supporting means to support the assembly; first shielding means to block radiation from the source in a first approximately vertical plane, fastened to the supporting means, and comprising an appendage opening dimensioned to allow a human appendage to pass through the first shielding means; and second shielding means to block radiation from the source in a second approximately vertical plane, fastened to the supporting means to allow the second shielding means to translate and rotate along an approximately vertical axis relative to the first shielding means.

A second aspect of the radiation shield assembly is provided, said second aspect comprising: a support arm constructed to support at least the majority of the weight of the shield assembly, the support arm having a longitudinal axis; a first vertical shield fastened to the support arm, and having an opening proximate to a lower end

dimensioned to admit a human appendage; a second vertical shield translatably and rotationally connected to the support arm to rotate about and translate along an axis that is approximately parallel to the longitudinal axis of the support arm; wherein the first vertical shield, first horizontal shield, second vertical shield, second horizontal shield, and lower vertical shield are all radiopaque.

5 In a third aspect a system for shielding a user from a bottom-mounted X-ray generator while said user attends to a prostrate patient positioned above the X-ray generator is provided, the system comprising: a table constructed to support the patient, the table having a longitudinal axis and a transverse axis; the X-ray generator positioned below the table; an image intensifier positioned above the table to receive X-rays projected from the X-ray generator; a radiopaque curtain shield extending downwardly from the table on at least a first side of the table; and a
10 radiation shield assembly comprising a support arm constructed to support the weight of the shield assembly and having a generally vertical longitudinal axis, a first shield assembly fastened to the support arm, comprising a first vertical shield, positioned proximate to the first side of the table and approximately parallel to the longitudinal axis of the table and an opening in the first vertical shield positioned above the table to allow the patient's arm to pass through the opening; and a second shield assembly rotatably and translationally fastened to the support arm to allow
15 the second shield assembly to rotate and translate about an axis approximately parallel to the longitudinal axis of the support arm, the second shield assembly comprising a second vertical shield positioned above the table; wherein the second vertical shield may be rotated about its axis to be approximately orthogonal to the longitudinal axis of the table or to be approximately parallel to the longitudinal axis of the table.

In a fourth aspect, a radiation shield assembly configured to block radiation emanating from a radiation
20 source is provided, the assembly comprising: a support arm constructed to support at least the majority of the weight of the shield assembly, the support arm having a longitudinal axis; a first vertical shield fastened to the support arm via a first radiopaque joint; and a second vertical shield translatably and rotationally connected to the support arm via a second radiopaque joint to rotate about and translate along an axis that is approximately parallel to the longitudinal axis of the support arm.

25 A fifth aspect provides a radiation shield assembly configured to block radiation emanation for a radiation source and comprises: supporting means to support the assembly, the supporting means comprising a base and a first translating means; first shielding means to block radiation from the source in a first approximately vertical plane, fastened to the first translating means, and comprising an appendage opening dimensioned to allow a human appendage to pass through the first shielding means; and second shielding means to block radiation from the source
30 in a second approximately vertical plane, fastened to the supporting means to allow the second shielding means to translate and rotate along an approximately vertical axis relative to the first shielding means; wherein the first translating means is configured to simultaneously translate the first and second shielding means relative to the base. In some preferred embodiments, the supporting means also comprises a second translating means connected to the first translating means, wherein the second shielding means is fastened to the second translating means and the
35 second translating means translates the second shielding means relative to said shielding means.

In a sixth aspect, a radiation shield assembly is configured to block radiation emanating from a radiation source and comprises: supporting means to support the assembly, the supporting means comprises a floor stand base, a mast extending from the floor stand base, a plurality of wheels supporting the floor stand base, and a plurality

of means for adjusting the positions of the wheels; first shielding means to block radiation from the source in a first approximately vertical plane, fastened to the mast, and comprising an appendage opening dimensioned to allow a human appendage to pass through the first shielding means; and second shielding means to block radiation from the source in a second approximately vertical plane, fastened to the mast to allow the second shielding means to translate and rotate along an approximately vertical axis relative to the first shielding means.

In a seventh aspect, a radiography method is provided, comprising: positioning any of the radiation shield assemblies above between a patient and a user, such that an appendage of the patient extends through an appendage opening in the shield assembly; inserting a medical device into vasculature of the appendage; and irradiating the patient using a radiation generator positioned such that radiation passes at least partially through the patient while being blocked from reaching the user by the shield assembly.

The above presents a simplified summary in order to provide a basic understanding of some aspects of the claimed subject matter. This summary is not an extensive overview. It is not intended to identify key or critical elements or to delineate the scope of the claimed subject matter. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

15 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1. An embodiment of the shield assembly showing the first and second vertical shields orthogonal to one another, in which the second vertical shield is lowered.

FIG. 2. The shield assembly shown in FIG. 1, in which the first and second vertical shields are orthogonal to one another, in which the second vertical shield is raised.

20 FIG. 3. The shield assembly shown in FIG. 1, in which the second vertical shield has been rotated to be roughly parallel to the first vertical shield.

FIG. 4. An embodiment of the shield assembly supported by a floor unit.

FIG. 5. An embodiment of the shield assembly supported by a ceiling-mounted boom.

FIG. 6. An embodiment of the shield assembly supported by a ceiling-mounted monorail.

25 FIG. 7. An embodiment of the shield assembly supported by a wall-mounted boom (wall is invisible).

FIG. 8. An embodiment of the shield assembly supported by a wall-mounted monorail (wall is invisible).

FIG. 9. An embodiment of the shield assembly having a sixth shield.

FIG. 10. A perspective view of an embodiment of the shielding system including an operating table, X-ray generator, and X-ray image intensifier. A patient is shown in an exemplary position.

30 FIG. 11. A front view of the embodiment of the shielding system in FIG. 10.

FIG. 12. Illustration of sensor positioning on an exemplary shield during dosimetry testing.

FIG. 13. Illustration of sensor positioning on a lead apron during dosimetry testing.

FIG. 14. Illustration of sensor positioning on shield during uniformity testing.

FIG. 15. Illustration of sensor results on shield in uniformity testing.

35 FIG. 16. An embodiment of the shield assembly comprising a flexible radiopaque member on the bottom of the first shielding means, and showing a pneumatic piston for raising and lowering the second horizontal shield.

FIG. 17. An embodiment of the shielding system including an operating table, X-ray generator, and X-ray image intensifier showing a radiopaque drape below the operating table.

FIG. 18. A front view of an embodiment of the shield assembly having a first and second translating means, where both translating means are retracted.

FIG. 19. A front view of an embodiment of the shield assembly having a first and second translating means, where the first translating means is extended and the second translating means is retracted.

5 FIG. 20. A front view of an embodiment of the shield assembly having a first and second translating means, where both translating means are extended.

FIG. 21. A cross sectional view of the first and second translating means of an embodiment of the shield assembly.

10 FIG. 22. A perspective view of an embodiment of the shield assembly having a first and second translating means, where both translating means are retracted.

FIG. 23. A perspective view of an embodiment of the shield assembly having a first and second translating means, where the first translating means is extended and the second translating means is retracted.

FIG. 24. A perspective view of an embodiment of the shield assembly having a first and second translating means, where both translating means are extended.

15 FIG. 25. A perspective view of an embodiment of the shield assembly having a first and second translating means, where the first and second vertical shields of the assembly are parallel to each other and both translating means are retracted.

20 FIG. 26. A perspective view of an embodiment of the shield assembly having a first and second translating means, where the first and second vertical shields of the assembly are parallel to each other, the first translating means is retracted, and the second translating means is extended.

FIG. 27. A top view of an embodiment of the shield assembly having a wheeled floor stand in a first configuration, where the first and second vertical shields of the assembly are parallel to each other.

FIG. 28. A top view of an embodiment of the shield assembly having a wheeled floor stand in a first configuration, where the first and second vertical shields of the assembly are orthogonal to each other.

25 FIG. 29. A top view of an embodiment of the shield assembly having a wheeled floor stand in a second configuration.

FIG. 30. A top view of an embodiment of the shield assembly having a wheeled floor stand in a third configuration, where the first and second vertical shields of the assembly are orthogonal to each other.

30 FIG. 31. A top view of an embodiment of the shield assembly having a wheeled floor stand in a third configuration, where the first and second vertical shields of the assembly are parallel to each other.

FIG. 32. An embodiment of a pivoting arm assembly for use with the shielding assemblies and system disclosed herein.

FIG. 33. An exploded view of the embodiment of the pivoting arm assembly shown in FIG. 32.

DETAILED DESCRIPTION

35 A. DEFINITIONS

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art of this disclosure. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is

consistent with their meaning in the context of the specification and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well known functions or constructions may not be described in detail for brevity or clarity.

5 The terms "about" and "approximately" shall generally mean an acceptable degree of error or variation for the quantity measured given the nature or precision of the measurements. Typical, exemplary degrees of error or variation are within 20 percent (%), preferably within 10%, and more preferably within 5% of a given value or range of values. For example, the terms "approximately parallel" or "approximately vertical" refer to an angle within an acceptable degree of error or variation from true parallel or vertical, such as within 45, 25, 20, 15, 10, or 1° of true parallel or vertical. Numerical quantities given in this description are approximate unless stated otherwise, meaning
10 that the term "about" or "approximately" can be inferred when not expressly stated. Claimed numerical quantities are exact unless stated otherwise.

It will be understood that when a feature or element is referred to as being "on" another feature or element, it can be directly on the other feature or element or intervening features and/or elements may also be present. In contrast, when a feature or element is referred to as being "directly on" another feature or element, there are no
15 intervening features or elements present. It will also be understood that, when a feature or element is referred to as being "connected", "attached", "fastened", or "coupled" to another feature or element, it can be directly connected, attached, fastened or coupled to the other feature or element or intervening features or elements may be present. In contrast, when a feature or element is referred to as being "directly connected", "directly attached", "directly fastened", or "directly coupled" to another feature or element, there are no intervening features or elements present.
20 Although described or shown with respect to one embodiment, the features and elements so described or shown can apply to other embodiments.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well (i.e., at least one of whatever the article modifies), unless the context clearly indicates otherwise.

25 Spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another when the apparatus is right side up as shown in the accompanying drawings.

Terms such as "at least one of A and B" should be understood to mean "only A, only B, or both A and B." The same construction should be applied to longer list (e.g., "at least one of A, B, and C"). In contrast, terms such as
30 "at least one A and at least one B" should be understood to require both A and B.

The terms "first", "second", "third," and the like are used herein to describe various features or elements, but these features or elements should not be limited by these terms. These terms are only used to distinguish one feature or element from another feature or element. Thus, a first feature or element discussed below could be termed a second feature or element, and similarly, a second feature or element discussed below could be termed a first
35 feature or element without departing from the teachings of the present disclosure.

The term "consisting essentially of" means that, in addition to the recited elements, what is claimed may also contain other elements (steps, structures, ingredients, components, etc.) that do not adversely affect the operability of what is claimed for its intended purpose as stated in this disclosure. This term excludes such other

elements that adversely affect the operability of what is claimed for its intended purpose as stated in this disclosure, even if such other elements might enhance the operability of what is claimed for some other purpose.

It is to be understood that any given elements of the disclosed embodiments of the invention may be embodied in a single structure, a single step, a single substance, or the like. Similarly, a given element of the disclosed embodiment may be embodied in multiple structures, steps, substances, or the like.

B. RADIATION SHIELD ASSEMBLY

A radiation shield assembly 100 is provided, configured to block radiation emanating from a radiation source and supported by a support means 145 to support the assembly 100. As shown in FIGS. 1-3, a first shielding means 105 is positioned in a first approximately vertical plane. The first shielding means 105 is fastened to the support means 145, and has an appendage opening 110 dimensioned to allow a human appendage to pass through the first shielding means 105. This gives access to the patient's arm (or alternatively the leg or torso) for the introduction of a medical device (such as an arthroscopic instrument) via the patient's vasculature.

A second shielding means 115 is positioned in a second approximately vertical plane, fastened to the support means 145, to allow the second shielding means 115 to translate and rotate along an approximately vertical axis relative to the first shielding means 105. The second shielding means 115 can thus be raised, lowered, or swung relative to the first shielding means 105 if necessary to gain access to the patient (compare FIGS. 1-3).

To protect the medical staff from radiation shining through the appendage 110, a third shielding means 120 may be positioned to block radiation from the appendage opening 110 in a first approximately horizontal plane that is approximately orthogonal to the first vertical plane. The third shielding means 120 may be fastened to the first shielding means 105 such that the third shielding means 120 translates and rotates with the first shielding means 105. In other words, the first 105 and third shielding means 120 may be static to one another in at least one configuration of the assembly 100 (although in some embodiments they might be mobile in at least one degree of freedom relative to the support arm 150 or other parts of the assembly 100). Additional (or alternative) protection may be provided in the form of a flexible radiopaque member on the bottom of the first shielding means 105. In an alternative embodiment of the shield assembly 100 a flexible radiopaque member 220 is used in place of the third shielding means 120, to intercept radiation emanating through the appendage opening 110. Examples of such flexible radiopaque members 220 include a shroud, a sleeve, a curtain, and one or more leaves of an iris port. They may be constructed from any suitable flexible and radiopaque material.

A fourth shielding means 125 may be positioned in a second approximately horizontal plane. The second horizontal plane is approximately orthogonal to the second vertical plane. The fourth shielding means 125 is fastened to the second shielding means 115 such that the fourth shielding means 125 translates and rotates with the second shielding means 115, for example along the support means 145. Additional protection may be provided in the form of a flexible radiopaque shroud on the bottom of the fourth shielding means 125. In an alternative embodiment of the shield assembly 100 a flexible radiopaque shroud is used in place of the fourth shielding means 125.

A fifth shielding means 135 may be present, positioned in a third approximately vertical plane that is approximately orthogonal to the second approximately vertical plane and to the second approximately horizontal plane, connected to the second shielding means 115 such that the fifth shielding means 135 translates and rotates with the second shielding means 115, and extending downward.

Some embodiments of the shield assembly 100 include a sixth shielding means 140, positioned in a fourth approximately vertical plane, connected to the first shielding means 105 such that the sixth shielding means 140 extends downward. The fourth approximately vertical plane may be approximately parallel to the first vertical plane. The sixth shielding means 140 may be positioned to protect the user's lower body from radiation. The sixth shielding means 140 may take any of numerous suitable forms, including one or more of a shield, a flexible drape, and an extension of the first shielding means 105.

The first 105 and second shielding means 115 may be configured to swing about a common axis, like a hinge (compare FIGS. 1 and 2). The axis may be the longitudinal axis of the support means 145, for example. In other embodiments, the first 105 and second shielding means 115 may each swing about each of two separate axes, in which said axes are approximately parallel to each other. In some such embodiments, the axes may both be approximately parallel to the longitudinal axis of the support means 145. By analogy, the first 105 and second shielding means 115 are enabled to swing relative to each other like the back and front covers of a book. In some embodiments the first 105 and second 115 shields are capable of assuming relative positions of about 180° from one another, such that they are approximately parallel and/or collinear when seen from above. Such an "open" configuration is useful to form a barrier along the entire length of a prostrate patient. In some embodiments the first 105 and second 115 shields are capable of assuming relative positions at or approaching 0° from one another, in which case they may be in contact with one another, or in close proximity and approximately parallel. In some embodiments the first 105 and the second shielding means 115 are configured to rotate relative to one another over an arc of at least about 90°. In some further embodiments, the first 105 and the second shielding means 115 are configured to rotate relative to one another over an arc of up to about 180°, and in further specific embodiments over an arc of from about 0-180°.

The first 105 and second shielding means 115 may also be configured to translate relative to one another, or to translate together along the support means 145 (compare FIGS. 1 and 2 and FIGS. 18-26). Advantageously, the ability to translate the shielding means 105, 115 both simultaneously and independently improves the ability to use the shield assembly 100 in various environments. The first 105 and second shielding means 115 can be adjusted to account for operating tables 305 having different heights, for patients having different dimensions, and for users of varying heights. The ability to translate independently in particular allows for fine tuning the configuration based on these variables. In addition, simultaneous translation allows for users to rapidly translate the shields away from a patient in the event there is a need for quick access to the patient. The shield assembly 100 may comprise a means for translating 225 at least one of the first 105 and second shielding means 115 along the support means 145. By way of example, such means for translating 225 could be an assist mechanism, a counterweight mechanism, an electric motor, a hydraulic mechanism, a pneumatic mechanism, a manual mechanism, or any combination of the foregoing.

In one preferred embodiment, the first 105 and second shielding means 115 are configured to translate together along the support means 145, and at least one of the first 105 and second shielding means 115 is configured to translate independently relative to the other. An example of this embodiment is shown in FIGS. 18-26, wherein a first translating means 230 translates the first 105 and second shielding means 115 together and a second translating means 235 translates the second shielding means 115 independently and relative to the first shielding

means 105. The first translating means 210 may comprise an outer sleeve 240 and a first inner sleeve 245, with at least a portion of one side of the first inner sleeve 245 being dimensioned to fit inside one end of the outer sleeve 240. The opposite side of the first inner sleeve may be secured to a base, such as a floor stand 170 or a ceiling or wall mount. Each of the first 105 and second shielding means 115 are connected (directly or indirectly) to the outer sleeve 240 such that they translate in unison when the outer sleeve slides along the first inner sleeve 245. The sleeves 240, 245 may be constructed from steel or any other suitable material. A first actuator 250, such as a linear actuator, is secured near one of its ends to the outer sleeve 240 and near the opposite end to the first inner sleeve 245. Any suitable connection means, such as a clevis pin, may secure the ends of the first actuator 250 to the outer sleeve 240 and first inner sleeve 245. Alternatively, the connection means may be another fastener, such as a screw, bolt and nut, clip, weld, or rivet. The first actuator 250 may be electrically connected to a control box (not pictured) that provides control signals to operate the first actuator 250. When the first actuator 250 is extended in the configuration shown in FIGS. 19-20 and 23-24, it causes the first 105 and the second shielding means 115 to be translated upward.

The second translating means 235 may comprise the same outer sleeve 240 (or another outer sleeve connected to the outer sleeve 240) and a second inner sleeve 255, with at least a portion of the second inner sleeve 255 being dimensioned to fit inside the opposite end of the outer sleeve 240. The first shielding means 105 is connected to the outer sleeve 240 and the second shielding means 115 is connected to the second inner sleeve 255, such that only the second shielding means 115 translates when the second inner sleeve 255 slides along the outer sleeve 240. The second inner sleeve 255 may be constructed from steel or any other suitable material. A second actuator 260, such as another linear actuator, may be secured near one of its ends to the outer sleeve 240 and near the other of its ends to the second inner sleeve 255. Any suitable connection means, such as a clevis pin, may secure the ends of the second actuator 260. The second actuator 260 may be electrically connected to the same or a different control box (not pictured) to provide control signals to operate the second actuator 260. When the second actuator 260 is extended in the configuration shown in FIGS. 20, 24, and 26, it causes the second shielding means 115 to be translated upward while the first shielding means 105 remains in place. Preferably the first 250 and second actuators 260 are disposed inside of the respective sleeves 240, 245, 255, but in some embodiments the actuators may be external to the sleeves. An example of a suitable actuator for the first 250 and second actuators 260 is the LA Series of in-line linear actuators that are commercially offered by Motion Control Products (Dorset, UK).

It should be understood that the first 230 and second translating means 235 may take many other forms. For instance, the sleeves 240, 245, 255 may be swapped such that a first outer sleeve is connected to an inner sleeve, which is connected at its opposite end to a second outer sleeve. Alternatively, other structures may be used instead of sleeves, or one or both of the first 105 and second shielding means 115 may connect directly to an end of an actuator. Other types of actuators may be used, such as a hydraulic actuator, a pneumatic actuator, a magnetic actuator, an electric motor, a manual actuator, an electric linear actuator, an electric rotary actuator, a fluid power linear actuator, a fluid power rotary actuator, a linear chain actuator, a manual linear actuator, a manual rotary actuator, a hydraulic piston, a comb drive, a thermal bimorph, a piezoelectric actuator, an electroactive polymer, and a servo mechanism. Or in some embodiments, the actuator may be replaced by other mechanisms that are capable of translating, or assisting a user in manually translating, the first and second translating means. For example, a

mechanical lift assist mechanism, such as a spring loaded pin, may enable a user to slide the sleeves along each other manually.

The support means 145 may be configured to allow the entire shielding assembly 100 to translate within the operating room, relative to an operating table 305. For example, the support means 145 could be configured to allow manual translation of the entire shielding assembly 100, or to allow mechanical translation of the entire shielding assembly 100 by means of one or more actuators. Some embodiments of the support means 145 constitute a support arm 150. The support arm 150 will be configured to support most of the weight of the assembly 100 (if not all of it). In the illustrated embodiment in FIGS. 2 and 3 the support arm 150 is an elongate steel structure, with a longitudinal axis that is generally vertical when the shield assembly 100 is in use. The support arm 150 can be constructed of any material of sufficient mechanical strength to support the assembly 100, and could be designed by one of ordinary skill in the art. Preferably the support arm 150 is constructed from material that is also radiopaque to the expected frequency and intensity of radiation. For example, some embodiments of the support arm 150 are opaque to X-rays at energies typical of radiology applications.

The support means 145 will be supported by the ceiling, floor, wall, or another structure. When floor-mounted (as in FIG. 4), it can be suspended by various structures. The support means 145 could be integrally mounted on the floor, or alternatively supported by a stand, either mobile or static.

Some embodiments of the supporting means 145 comprise an approximately vertical mast 155. The supporting means 145 is capable of supporting the shield assembly 100 to some extent. For example, some embodiments of the supporting means 145 are capable of supporting the majority of the weight of the assembly 100. In further embodiments, the supporting means 145 is capable of supporting about the entire weight of the assembly 100, or the entire weight. The mast 155 may be supported by various means.

In some embodiments of the radiation shield assembly 100, the mast 155 is supported by a floor stand 170. The floor stand 170 may further comprise a plurality of wheels 175 to allow easy deployment and removal of the assembly 100. In some preferred embodiments, the wheeled floor stand 170 includes a plurality of means for readjusting 265 the configuration of the plurality of wheels 175. Advantageously, the plurality of means for readjusting 265 improves use of the radiation shield assembly 100 because the wheels 175 can be rearranged to maximize stability of the assembly 100, to accommodate use with different operating tables, or to prevent interference with a user's ambulation.

In one preferred embodiment having means for readjusting 265 (shown in FIGS. 18–31), the wheeled floor stand 170 comprises a floor stand base 270, a plurality of adjustable arms 275 rotatably connected to the floor stand base 270, and at least one wheel 175 attached to each of the adjustable arms 275. The plurality of adjustable arms 275 may be connected to the base 270 using any connection that allow the arms to be adjusted relative to the base, and preferably, the stand 170 may further include a means for temporarily tightening or locking the arm in place. In some embodiments, the connection is a hinge or pivot 280, and the locking means are a clamp 285. Alternatively, in some embodiments, each arm 275 may be connected to the base 270 by a screw or bolt that serves as both a pin about which the arm 275 rotates and the means for temporarily locking the arm 275 in place. Each connection means preferably provides each adjustable arm 275 with a certain degree of freedom to rotate relative to the base 270. In some embodiments, each arm is capable of rotating preferably at least about 30° relative to the base, more

preferably at least about 60° relative to the base, and even more preferably at least about 90° relative to the base. Many embodiments, however, also include a stop on each side of the arms 275 to prevent over-rotation of the arms 275 such that the wheeled floor stand 170 would become unstable. Optionally, the arms 275 may include means for readjusting the location of the wheels 175 along the arms 275. For instance, in some embodiments, the arm 275 may be telescoping or otherwise include means for extending and retracting the wheel 175 on the arm. The wheels 175 may be any wheel suitable for supporting the load of the radiation shield assembly 100. In many preferred embodiments, the wheels 175 are swivel caster wheels, which advantageously can roll in any direction.

FIGS. 27 through 31 provide examples of how the wheeled floor stand 170 may be advantageously reconfigured for different uses. In the embodiment depicted, the wheeled floor stand 170 includes four adjustable arms 275 rotatably connected to the base 270 and one wheel 175 attached to the end of each adjustable arm 275. The adjustable arms 275 have approximately 90° of freedom to rotate about the base 270. In the first configuration shown in FIGS. 27 and 28, the adjustable arms 275 are oriented at approximately 45° relative to the sides of the base. This first configuration provides maximum stability because it provides the widest base to resist tipping of the assembly 100. A second configuration is shown in FIG. 29, wherein one of the adjustable arms 275 has been rotated to one of its extreme positions. This second configuration may be advantageous where an operating table includes a base or legs that interfere with placing the radiation shield assembly 100 in sufficient proximity to the table or advantageous where a user (e.g. a surgeon) needs the ability to walk about without the risk of tripping over the arm 275. A third configuration is shown in FIGS. 30 and 31. This third configuration is the most compact arrangement, with each arm 275 being rotated to an extreme position such that all of the arms are parallel to one another. This configuration may be advantageous if there is limited space in the operating room or if the assembly 100 needs to be stored in a narrow space.

Embodiments of the shield assembly 100 may have position-adjustable wheels 175. In some such embodiments, a mechanism 265 for adjusting the positions of the wheels 175 comprises a pivot linkage 340 connected to an arm member 310 and a pivot shaft 410 within the pivot linkage 340. The pivot shaft 410 and linkage 340 are configured to permit the arm member 310 to pivot about the axis of the pivot shaft 410. Such a configuration has the advantage of mobility and the ability to bear heavy loads. In some embodiments of the shield assembly 100 the mechanisms 265 for adjusting the positions of the wheels 175 comprises a locking mechanism 265 configured to lock the wheels 175 in a particular position. Such embodiments allow the wheels 175 to be placed in a convenient or advantageous position and locked in that position to prevent repositioning of the wheels 175 if the shield assembly 100 is pushed or jostled. One example of such a locking mechanism 265 is a locking collar 460 and a locking knob configured to tighten and loosen the locking collar 460. The locking collar 460 can be placed around a pivot shaft 410 about which the arm assembly 275 pivots.

FIGS. 32-33 shows one preferred embodiment of a pivoting arm assembly 275 for the wheels 175. This embodiment comprises an arm member 310 attached to a swivel caster 330 at a first end and attached to a pivot linkage 340 on the other (second) end. The arm member 310 may be attached to the pivot linkage 340 and swivel caster 330 by any means that will sufficiently bear the weight of the shield assembly 100. In the illustrated embodiment the arm member 310 is welded to the pivot linkage 340 and is fastened to the swivel caster 330 by one or more fasteners. A pivot shaft 410 in the pivot linkage 340 allows the arm 310 to pivot relative to the stand 170.

The pivot shaft 410 is connected to an arm mounting plate 440 via a plurality of fasteners (screws in this embodiment), and the mounting plate 440 is connected to the stand 170 via a plurality of fasteners (screws and washers in this embodiment). Two flanged sleeve bearings 420 surround the pivot shaft 410, and an arm retainer 430 holds a locking knob 450 in place. The locking mechanism 265 shown includes a locking collar 460 that can be tightened to prevent the arm 275 from pivoting about the pivot shaft 410. The tightening means shown is a lock knob 450 that is placed through the arms of the locking collar 460 and is held in place with a retaining ring 470.

FIGS. 32 and 33 show a specific embodiment of the wheel 175 on the arm member 310, in the form of a swivel caster 330. The swivel caster 330 is shown fastened to a caster plate 320 by a plurality of fasteners (screws with washers in this embodiment). The caster wheels 330 can be locked against rolling with a brake.

In further embodiments of the system, the mast 155 is suspended by an overhead boom 160 (see FIGS. 5 and 7). The use of an overhead boom 160 can provide easy mobility to even a relatively massive assembly 100, allowing the assembly 100 to be emplaced and removed relative to the patient quickly and easily. Various configurations utilizing the boom 160 are contemplated. For example, the mast 155 may be configured to rotate about the longitudinal axis of the overhead boom 160, or to pivot relative to the overhead boom 160. The mast 155 may be capable of translating along the longitudinal axis of the overhead boom 160. In further embodiments of the system, the overhead boom 160 is supported by a second mast 165. The second mast 165 may in turn be supported on a wheeled floor stand 170, mounted on the ceiling, or mounted on a wall. For example, the second mast 165 may be supported by a wall-mounted rail 180 or ceiling-mounted rail 185 (see FIGS. 6 and 8); in such embodiments the second mast 165 may be capable of translating along the wall-mounted rail 180 or ceiling-mounted rail 185. As another example, the second mast 165 may be supported by a wall-mounted swinging arm 190 or ceiling-mounted swinging arm 195 (see FIGS. 5 and 7). In a further embodiment, the second mast 165 may be supported by a swinging arm that is in turn supported by a wall-mounted rail 180 or ceiling-mounted rail 185, and wherein the swinging arm is capable of translating along the wall-mounted rail 180 or ceiling-mounted rail 185.

In some embodiments in which the third horizontal shielding means 120 is present, the first shielding means 105 and the third shielding means 120 are configured to translate together vertically. For example, the first shielding means 105 and the third shielding means 120 may be configured to translate together along the support means 145. The degree of translation may be configured to optimize the shielding of the user from X-rays while the user is standing or sitting. For example, the first shielding means 105 may be configured to translate along such that in a first position a top edge of the first shielding means 105 is at least about the height of an adult human above the floor. Taking into account normal human dimensions, such height could be 175 cm, 180 cm, 185 cm, 190 cm, 195 cm, or 200 cm above the floor.

Similarly, the first shielding means 105 itself will be dimensioned to provide adequate radiation protection when in position during use. For example, it may have a height of at least about the distance from the upper surface of an operating table 305 to an average human's full height. In various embodiments the first shielding means 105 has a height of at least about the distance from the upper surface of an operating table 305 to a height of 175 cm, 180 cm, 185 cm, 190 cm, 195 cm, or 200 cm above the floor when said operating table 305 is on the floor. A greater height has the advantage of shielding a greater area from X-rays, whereas a lesser height has the advantage of reduced weight and cost.

In the illustrated embodiment in the figures, the first shielding means 105 is intended to be positioned roughly parallel to the long axis of the operating table 305, and protect a user's upper body from X-rays emitted from a point below the table 305. In the illustrated embodiment the first shielding means 105 is a generally planar vertical shield fastened to the support arm 150. Of course, the first shielding means 105 could fulfill its function even if not exactly vertical, and could be designed to be inclined as necessary or desirable to customize the shielded area. Some embodiments of the first vertical shield 105 will be designed to extend above the head of the user, to prevent direct radiation from reaching the user's head. The first vertical shield 105 could be designed to extend above the head of a standing user, or in some circumstances a sitting user. The embodiment of the first vertical shield 105 shown has a length sufficient to extend from the head of the patient to about the waist of the patient. Such a configuration is particularly useful in procedures in which radiography is used to visualize the patient's thoracic region. The length could be increased to provide broader protection, but such increase in length must be balanced with the additional weight and reduced flexibility in configuration that will accompany such changes.

In the illustrated embodiment an opening 110 is shown in the first shielding means 105 to allow the patient's arm to extend from the shielded area. The opening 110 may optionally contain flexible shielding material such as a radiopaque curtain or flexible flanges 220. The opening 110 as shown is semicircular, but may take any shape that allows the patient's appendage to extend through the shield. The opening 110 presents a possible path for radiation leaks. The third shielding means 120 is positioned to block radiation shining through the opening 110 from irradiating the user. In the illustrated embodiment, the third shielding means 120 is a horizontal shield positioned over the opening 110 and orthogonal to the first vertical shield 105. This particular configuration is useful to block radiation from an emitted position below the opening 110 and on the side of the vertical shield opposite to where the user is standing. The third shielding means 120 can be oriented differently to accommodate a different emitted position relative to the opening 110.

In the illustrated embodiment of FIGS. 1-3, the second shielding means 115 is configured to rotate and translate relative to the first shielding means 105 to allow the assembly 100 to be adjusted according to the dimensions of the patient and to allow the assembly 100 to be reconfigured to provide varying degrees of access to the patient and protection from radiation. In the illustrated embodiment it takes the form of a second approximately vertical shield 115 connected to the support arm 150 so as to allow it to rotate about the longitudinal axis of the arm and translate parallel to the same longitudinal axis. In FIG. 1 the second vertical shield 115 is shown in a position orthogonal to the first vertical shield 105. Such a configuration is useful in practice to give the user access to a patient's legs when the second vertical shield 115 crosses the patient's body. It could also be lowered to the table 305 to form a complete shield if the patient is positioned with the head closest to the second vertical shield 115. In FIG. 3 the second vertical shield 115 is shown generally parallel to the first vertical shield 105.

The fourth shielding means 125 functions to block radiation that might shine from under the second shielding means 115 when the second shielding means 115 is positioned above the table 305. In the accompanying figures the fourth shielding means 125 is shown as a horizontal shield with a cutout 130. This trapezoidal cutout 130 functions to provide access to a patient's groin during the procedure, which can be useful to allow access to the femoral vein for arthroscopic insertion. The cutout 130 is a useful, but optional, feature of the second horizontal shield 125. In the illustrated embodiment the second horizontal shield 125 is positioned to intercept radiation emitted

from below an operating table 305, but this structure could be positioned differently to intercept radiation from another direction.

The fifth shielding means 135, when present, functions to intercept radiation from exposing a user's lower body when the user is located on the opposite side of the support arm 150 as the radiation source. Such a structure is not generally necessary below the first shielding means 150 because operating tables typically are equipped with leaded curtains hanging from the operating table for procedures that require radiological monitoring. However, the curtain does not always run the entire length of the table or extend along the width of the table.

Most of the surface area of the shielding means are opaque to the frequencies and intensities of radiation which they are intended to block. Some embodiments of the shielding means may be entirely radiopaque. Exemplary materials that are radiopaque to X-rays include lead plates, lead filings, leaded acrylic glass, and polymer suspensions of lead particles. Other heavy metals, such as barium, may be used, although lead has the advantage of a very high atomic number and stable nuclides. As thickness increases along the radiation vector radiopacity increases. In designing the shielding means a balance will be struck between achieving adequate radiopacity and limiting the weight of the apparatus. For example, some embodiments of the lead shield will be about 0.5-1.5 mm thick. Further embodiments of the lead shield will be about 0.8-1.0 mm thick. Less dense materials, such as leaded acrylic, must be thicker to achieve the same level of radiopacity as lead. For example, some embodiments of the leaded acrylic shield will be about 12-35 mm thick. Further embodiments of the leaded acrylic shield will be about 18-22 mm thick. Lead barium type glass is another suitable material. For example, some embodiments of the lead barium type glass shield will be about 7-17 mm thick. Further embodiments of the lead barium type glass shield will be about 7, 9, 14, or 17 mm thick. Comparing these exemplary materials, lead has the advantage of better radiopacity per unit thickness, while leaded acrylic and lead barium type glass have the advantage of visual transparency and X-ray opacity. In some embodiments of the assembly 100 at least one of the first through fifth shielding means 105, 115, 120, 125, 135 is transparent to visible light. In such embodiments the transparent shielding means may have an optical transmissivity that equals or exceeds one of 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 99%, and 100%.

Outside of the context of any specific material, the radiopacity of the shielding means can be expressed as millimeter-lead equivalents. In various embodiments of the system, at least one of the first 105, second 115, third 120, fourth 125, or fifth shielding means 135 has a radiopacity of least 0.5 mm, 1.0 mm, 1.5, 2, 3, or 3.3 mm lead equivalent.

Any of the shielding means described above may be joined to one another or joined to the support means 145 via a radiopaque joint 205. Such a radiopaque joint 205 will minimize the transmission of radiation from the generator through the joint 205. This can be accomplished between plates for example by joining the plates with a sufficiently narrow gap that a straight line cannot be traced from the radiation source through the gap when in position as intended at the operating table 305. Such joints 205 can be constructed using, for example, radiopaque braces or lap joints. A radiopaque joint 205 with a support arm 150 can be constructed, for example, using a radiopaque sleeve around the support arm 150 fastened to the shielding means.

The radiation shield assembly 100 is supported by the support arm 150 and positioned to locate a first and second shield assembly between the patient and the user. The first shield assembly is fastened to the support arm

150, comprising the first generally vertical shield 105 and the first generally horizontal shield 120. The second shield assembly is also fastened to the support arm 150 so as to rotate and translate along the longitudinal axis of the support arm 150 relative to the first shield assembly. The second shield assembly comprises a second generally vertical shield 115 positioned above the table 305; a second generally horizontal shield 125 connected to the second
5 vertical shield 115 and positioned above the table 305; and a lower generally vertical shield 135 extending from the second horizontal shield 125 to below the table 305. The second vertical shield 115 may be rotated about its axis to be approximately orthogonal to the longitudinal axis of the table 305 or to be approximately parallel to the longitudinal axis of the table 305.

The shielding assembly may be part of a greater system comprising an operating table 305, X-ray generator 310, and image intensifier 315 (see FIGS. 10 and 11). The X-ray generator 310 will be positioned to direct X-rays through the table 305 and to the image intensifier 315 on the other side, as is known in the art. The generator 310 and image intensifier 315 may be mutually mounted on a C-arm 320, for example. The operating table 305 will frequently have a radiopaque curtain 325 hanging from at least one side of the table 305. The curtain 325 may also extend around two or more sides of the table 305. The curtain 325 is particularly useful when the system is
10 configured with the X-ray generator 310 below the table 305. The patient will generally be "prostrate," meaning that the patient is lying on the table 305 in any suitable orientation, including supine, prone, and lying on the side. Conventionally the patient will be positioned on a table 305, between an X-ray generator 310 and an image intensifier 315, for example as commonly mounted on a C-arm 320. In the accompanying illustrations the X-ray generator 310 is shown below the patient, which is one commonly used configuration, but not the only configuration in which the system could be used. The table (such as an operating table 305) is capable of supporting the patient. Depending on the age and size of the patient, various configurations of operating table 305 could be used. The image intensifier 315 will be positioned to receive X-rays projected from the X-ray generator 310 (such as being positioned above the table 305 if the X-ray generator 310 is below). Typically a radiopaque curtain shield 325 extends downwardly from the table 305 on the side one which medical personnel will be working (the "first side"). The first shielding means 105
15 may be positioned to contact the table's edge along its long dimension, or such that the bottom edge of the first shielding means 105 is below the surface of the table 305 along its long dimension. The second shielding means 115 may also be positioned parallel to the long dimension of the table 305, so as to form a barrier between the user and the patient's lower extremities. In such a configuration the second shielding means 115 will also be positioned so that its lower edge either contacts the table 305 or hangs below the elevation of the table's surface so as to block radiation from reaching the user. Alternatively, the second shielding means 115 may be rotated relative to the first shielding means 105 at an approximately orthogonal angle, so as to cross the operating table 305 laterally. If the second shielding means 115 has a cutout at the bottom to accommodate the patient's body, this can provide the user access to the patient's lower extremities, for example to gain access to the femoral vein. The second shielding means 115 can be elevated along the support means 145 appropriately to accommodate the patient's physiology. It
20 is also contemplated that the second shielding means 115 could be positioned laterally across the table 305, and in contact with the table 305, for example if the patient's head is located proximate to the second shielding means 115 (not shown). Thus a medical device, such as a catheter or an arthroscopy instrument, can be inserted into the
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patient's vasculature through an arm or leg extending past the first 105 or second shielding means 115 while minimizing the radiation that reaches the user.

A method of radiology is provided, using any embodiment of the radiation shield assembly 100 disclosed above. The method comprises positioning any one of the radiation shield assemblies or systems above between a patient and a user, such that an appendage of the patient extends through an appendage opening 110 in the shield assembly; inserting a medical device into vasculature of the appendage; and irradiating the patient using a radiation generator 310 positioned such that radiation passes at least partially through the patient while being blocked from reaching the user by the shield assembly 100.

C. EXAMPLE

Analysis was performed at the testing location for the purpose of the evaluation of an embodiment of the shielding system. Secondary scattered radiation was created with two CIRS 76-125 patient equivalent phantoms using a Siemens C-ARM X-ray source that was normally used for fluoroscopy operations. Analysis was performed to survey scattered radiation through custom shielding and compared against no protective shielding versus lead apron results.

The test sample was a custom lead-acrylic radiation protective shield fabricated specifically for C-ARM applications. The shielding consists of a series of custom fabricated, 18.8 mm thick lead-acrylic material (Sharp Mfg., West Bridgewater, MA), having a minimum density of 4.36 g cm⁻³, a refractive index of 1.71, a thermal expansion coefficient of 8E-6/° C (30-380°), and a Knoop hardness of 370. Specifically, the material is lead barium type glass of high optical grade with greater than 60 percent heavy metal oxide, at least 55 percent PbO. The lead equivalency of this material is guaranteed by the manufacture to be greater than 3.3 mm Pb. The custom fabricated shielding design with labels was constructed generally as shown in FIG 4. With the exception of the support system which is made from aluminum, the shielding system is entirely made from the exact same source material. All the panels were fabricated and cut by the manufacturer.

Scattered radiation was created using a Siemens Model 10394668 with Serial No 1398 Medical C-ARM source through the CIRS 76-125 Lead-Acrylic Patient Equivalent Phantom extremity and torso used to represent a patient torso with an arm (Computerized Imaging Reference Systems, Inc., Norfolk, VA). The Siemens Medical C-ARM has a reported inherent filtration of 0.8 mm Al at 70 kV along with the diamentor chamber, size B with 0.2 mm Al at 70 kV. No secondary filtration was used for the measurements discussed in this report.

Radiation measurements were made using a Victoreen 470A Panoramic Survey Meter with Serial No 2079. Calibration was performed using a Cs-137 isotope source at the University of Alabama at Birmingham (UAB) Radiology Labs.

Comparisons with lead aprons were carried out using two products, a Techno Aide lead apron with serial no T116969, and a Xenolite with serial no 1 02 001. According to the manufactures' information, both lead aprons have a lead equivalency of 0.5 mm Pb.

Test methods and procedures were guided by ASTM F3094 (ASTM International "Standard Test Method for Determining Protection Provided by X-ray Shielding Garments Used in Medical X-ray Fluoroscopy from Sources of Scattered X-Rays" *ASTM Volume 11.03 Occupational Health and Safety; Protective Clothing* (2017)), IEC 61331-1 (International Electrotechnical Commission, "Protective devices against diagnostic medical X-radiation - Part 1:

Determination of attenuation properties of materials" (2014) available at <https://webstore.iec.ch/publication/5289>), and a medical physicist. A testing methodology was developed and created prior to being performed. ASTM F3094 and IEC 61331-1 are incorporated herein by reference so as to enable a person of ordinary skill in the art to perform the protocols.

5 The custom fabricated lead-acrylic shielding was tested for the attenuation of scattered radiation as well as uniformity. In addition, measurements were made along the major edges of the total shield as well as a semi-circular section where the physician will place the patient's arm during procedure. Equivalent scattered radiation measurements were compared against 0.5 mm lead equivalent lead aprons. The final set of measurements were made with no shielding in place. All data was recorded on site. All measurements were recorded using a 10 second exposure time and repeated at a minimal of three times. The criteria of protection rating was based on the measured, scattered radiation attenuation from an 81 kV X-ray C-ARM source.

10 Radiation detected by the Victoreen 470A represents scattered X-ray radiation created by the interaction of X-rays with the CIRS 76-125 patient equivalent phantom. The distance between the C-ARM X-ray source was set at the default distance used for patient examinations of 17 inches or 43.18 cm. This protocol is referred to herein as the "Modified ASTM F3094/ IEC 61331-1 Protocol."

Average scattered radiation measurements made with no shielding can be found in Table 1 below. All measurements were made in triplicate at a minimal. Radiation measurements were first made with the custom, fabricated shielding in place so that the exact position of the shield, phantom, and detector could be marked for subsequent measurements without any shielding or comparison measurements with the two lead aprons.

20 **Table 1: Summary of Phantom, Scattered Exposure without Protective Shielding**

Measurement Region	mR/hr Avg (Std Dev)
Centered	3.725 (0.095)
Bottom, Edge	1.65 (0.1)
Right, Edge	1.67 (0.057)
Top, Edge	2.7 (0.0)
Left, Edge	3.55 (0.057)
Bottom, Left, Edge	2.267 (0.058)

All measurements were made in triplicate at a minimal. Average scattered radiation measurements made with the custom, fabricated lead-acrylic shield (FIG. 12) can be found in Table 2 below. Measurements made through the custom fabricated shielding as well as currently accepted lead aprons are very low intensity and only slightly above background radiation. As a result, replicate measurements yielded a low standard deviation as compared to measurements without any shielding in Table 1 above.

25 **Table 2: Summary of Phantom, Scattered Exposure with Custom Fabricated Shielding**

Measurement Region	mR/hr (Std Dev)
Centered	0.083 (0.029)
Bottom, Edge	0.15 (0.0)

Right, Edge	0.15 (0.0)
Top, Edge	0.15 (0.077)
Left, Edge	0.2 (0.0)
Bottom, Left, Edge	0.25 (0.0)

In addition, measurements were performed to detect the levels of radiation in the precise position of the physician while in use. Measurements were specifically made at the physician's groin height as well as the physician's chest height. The results are summarized below in Table 3.

Table 3: Summary of Phantom, Scattered Exposure with Custom Fabricated Shielding

Measurement Region	mR/hr (Std Dev)
Physician Mid-Chest	0.0773 (0.0343)
Physician Groin	0.21 (0.022)

- 5 Scattered radiation measurements were then made with a Techno Aide 0.5 mm lead equivalent apron and can be found in Table 4 below. Measurements were made through a lead apron (FIG. 13) for the purpose of comparing an accepted, medical radiation protective device to the one being proposed in this study. Strict comparison under actual, real-life positions was used in an attempt to provide the most accurate information and comparison. A graphical representation has been created below with Table 4 summarizing the observed averages for
- 10 scattered radiation measurements with standard deviations.

Table 4: Summary of Phantom, Scattered Exposure with Techno Aide 0.5 mmPb Lead Apron

Measurement Region	mR/hr (Std Dev)
Centered	0.075 (0.027)
Bottom, Edge	0.075 (0.029)
Right, Edge	0.1125 (0.025)
Top, Edge	0.1 (0.0)
Left, Edge	0.1 (0.0)

- Once survey measurements had been completed on the first 0.5 mm lead equivalent apron, a second lead apron was selected, and replicate measurements were performed exactly as done for the Techno Aide product. The average scattered radiation measurements are summarized below in Table 5 for the second XenoLite lead apron
- 15 comparison.

Table 5: Summary of Phantom, Scattered Exposure with XenoLife 0.5 mmPb Lead Apron

Measurement Region	Avg (Std Dev), mR/hr
Centered	0.05 (0.0)
Bottom, Edge	0.1 (0.0)
Right, Edge	0.05 (0.0)
Top, Edge	0.1 (0.0)
Left, Edge	0.067 (0.03)

Two shield components were measured as a representative for uniformity to ensure that no voids are present in the overall shield apparatus. These measurements were performed in the same manner as described above. The results can be found in FIGS. 14 and 15. The data is represented in the same format as in Tables 1-4 with the reported average scattered radiation measurement values and standard deviation in parentheses.

As demonstrated by FIG. 14, no significant voids were observed while performing survey measurements of Main Panel A. Radiation measurements yielded values very similar to previous measurements previously reported from centering on individual panels. An additional note, replicate measurements were essentially identical and yielded a low standard deviation.

As demonstrated by FIG. 15, the four regions were surveyed for uniformity with Main Body Panel A. The average measured radiation value is represented above with the standard deviation in parenthesis. A quick comparison between FIGS. 14 and 15 show very similar values between Main Panel A and Main Body Panel A.

Pass/fail criteria is based on the pre-accepted performance criteria of industrial grade lead-acrylic custom fabricated into a C-ARM shielding apparatus. In addition, this shielding apparatus must provide protection equal to or greater than currently, accepted lead aprons used for the same application. Using the state of Alabama guide that a medical worker receives no more than 5 Rem per year as a shallow dose equivalent and used as the pass/fail criteria.

The study endpoints are based on the successful completion of all measurements dictated by Alabama State guidelines for protective devices used by physicians in C-ARM patient examinations. The study endpoint is specifically based on comparable measurements made using currently accepted lead aprons against no protective shielding of any kind versus the custom fabricated lead-acrylic shielding.

The levels of radiation detectable behind the sponsoring custom, fabricated lead-acrylic shielding were consistent with calculated values based on the manufacture's performance criteria. The levels of radiation detected are within the maximum allowable permitted dose of radiation for medical workers.

When compared to currently accepted lead aprons, relatively equal levels of attenuated radiation were detected behind the custom shielding. The performance of the custom shielding and lead aprons is due in large part to the detection of secondary radiation in this case, as opposed to primary radiation. Scatter equivalent primary radiation is used to determine the official lead equivalency of a material. Under actual scatter conditions such as those used in this study, the measurable amount of secondary radiation is so low that one would not expect measurable differences between materials with different lead equivalency.

Using the currently accepted dose equivalent of 5 rems (R) per year, 52 work-weeks a year, and 40-hours of exposure a week, total annual exposure with this shielding prototype was calculated. According to the highest observed radiation measurements made during this study of 0.25 mR/hr, a 40-hour work week would yield a total dose of 10 mR per week. Using the average value calculated from all measurements of 0.164 mR/hr, a 40-hour work-week would yield a total dose of 6.6 mR per week. Using the maximum possible dose of 10 mR per week, the custom fabricated shielding apparatus would yield a total dose of 520 mR or 0.52 R annual.

D. CONCLUSION

The foregoing description illustrates and describes the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure. Additionally, the disclosure shows and describes only certain embodiments of the processes, machines, manufactures, compositions of matter, and other teachings disclosed, but, as mentioned above, it is to be understood that the teachings of the present disclosure are capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the teachings as expressed herein, commensurate with the skill and/or knowledge of a person having ordinary skill in the relevant art. The embodiments described hereinabove are further intended to explain certain best modes known of practicing the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure and to enable others skilled in the art to utilize the teachings of the present disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure are not intended to limit the exact embodiments and examples disclosed herein. Any section headings herein are provided only for consistency with the suggestions of 37 C.F.R. § 1.77 or otherwise to provide organizational queues. These headings shall not limit or characterize the invention(s) set forth herein.

CLAIMS

The following is claimed:

1. A radiation shield assembly, configured to block radiation emanating from a radiation source, the assembly comprising:
 - (a) supporting means to support the assembly, said supporting means comprising a base and a first translating means;
 - (b) first shielding means to block radiation from the source in a first approximately vertical plane, fastened to the first translating means, and comprising an appendage opening dimensioned to allow a human appendage to pass through the first shielding means; and
 - (c) second shielding means to block radiation from the source in a second approximately vertical plane, fastened to the supporting means to allow the second shielding means to translate and rotate along an approximately vertical axis relative to the first shielding means,wherein said first translating means is configured to simultaneously translate said first and second shielding means relative to said base.
2. The radiation shield assembly of claim 1, said supporting means comprising a second translating means connected to said first translating means, wherein said second shielding means is fastened to said second translating means and said second translating means translates said second shielding means relative to said first shielding means.
3. The radiation shield assembly of any one of the claims above, said first translating means comprising an outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve.
4. The radiation shield assembly of any one of the claims above, said first translating means comprising an actuator disposed in said outer and inner sleeves and connected at opposite sides to said outer and inner sleeves.
5. The radiation shield assembly of any one of claims 2-4, said first translating means comprising an outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve; and said second translating means comprising said outer sleeve and a second inner sleeve dimensioned to fit at least partially inside the other end of said outer sleeve.
6. The radiation shield assembly of claim 5, said first translating means comprising a first actuator disposed in said outer and first inner sleeves and connected at opposite sides to said outer sleeve and said first inner sleeve, and a second actuator disposed in said outer and second inner sleeves and connected at opposite sides to said outer sleeve and said second inner sleeve.
7. The radiation shield assembly of claim 6, wherein each of said first and second actuators is a linear actuator.
8. The radiation shield assembly of any one of the claims above, comprising a plurality of wheels supporting said base, and a plurality of means for adjusting said wheels.
9. The radiation shield assembly of any one of the claims above, wherein said base is a floor stand, a wall mount, or a ceiling mount.
10. The radiation shield assembly of claim 2, said first translating means comprising a first outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said first outer sleeve; and said second translating

means comprising a second outer sleeve and said inner sleeve dimensioned to fit at least partially inside one end of said second outer sleeve.

11. A radiation shield assembly, configured to block radiation emanating from a radiation source, the assembly comprising:
 - (a) supporting means to support the assembly, said supporting means comprising a floor stand base, a mast extending from said floor stand base, a plurality of wheels supporting said floor stand base, and a plurality of means for adjusting the positions of said wheels;
 - (b) first shielding means to block radiation from the source in a first approximately vertical plane, fastened to the mast, and comprising an appendage opening dimensioned to allow a human appendage to pass through the first shielding means; and
 - (c) second shielding means to block radiation from the source in a second approximately vertical plane, fastened to the mast to allow the second shielding means to translate and rotate along an approximately vertical axis relative to the first shielding means.
12. The radiation shield assembly of claim 11, said means for adjusting comprising a plurality of arms adjustably connected to said floor stand base, wherein at least one of said plurality of wheels is secured to one of said arms.
13. The radiation shield assembly of claim 12, wherein a hinge rotatably connects said plurality of arms to said floor stand base.
14. The radiation shield assembly of any one of claims 11-13, wherein each means for adjusting comprises a clamp to temporarily lock the position of said arm relative to said floor stand base.
15. The radiation shield assembly of any one of claims 11-14, wherein said plurality of arms are capable of rotating at least about 30° relative to said floor stand base.
16. The radiation shield assembly of any one of claims 11-15, wherein each means for adjusting includes a stop for preventing rotation of said arms past said stop.
17. The radiation shield assembly of any one of claims 11-16, wherein said plurality of wheels are caster wheels.
18. The radiation shield assembly of any one of claims 11-17, wherein at least one of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; and a pivot shaft within the pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft.
19. The radiation shield assembly of any one of claims 11-18, wherein each of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; and a pivot shaft within the pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft.
20. The radiation shield assembly of any one of claims 11-19, wherein the means for adjusting the positions of said wheels comprises a locking mechanism configured to lock the wheels in a particular position.
21. The radiation shield assembly of any one of claims 11-20, wherein the means for adjusting the positions of said wheels comprises a locking mechanism, said locking mechanism comprising a locking collar and a locking knob configured to tighten and loosen the locking collar.
22. The radiation shield assembly of any one of claims 11-21, wherein each of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; a pivot shaft within the

- pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft; a locking collar around the pivot shaft; and a locking knob configured to tighten and loosen the locking collar to lock and unlock the wheels in a particular position.
23. The radiation shield assembly of any one of the claims above, comprising third shielding means to block radiation from the appendage opening in a first approximately horizontal plane that is approximately orthogonal to the first vertical plane, and fastened to the first shielding means such that the third shielding means translates and rotates with the first shielding means.
 24. The radiation shield assembly of any one of the claims above, comprising fourth shielding means to block radiation from the source in a second approximately horizontal plane that is approximately orthogonal to the second vertical plane, and fastened to the second shielding means such that the fourth shielding means translates and rotates with the second shielding means.
 25. The radiation shield assembly of any one of the claims above, comprising fifth shielding means to block radiation from the source in a third approximately vertical plane that is approximately orthogonal to the second approximately vertical plane and to the second approximately horizontal plane, connected to the second shielding means such that the fourth shielding means translates and rotates with the second shielding means.
 26. The radiation shield assembly of any one of the claims above, comprising sixth shielding means to block radiation from the source in a fourth approximately vertical plane that is approximately parallel to the first approximately vertical plane, wherein the sixth shielding means is secured to the first shielding means.
 27. The radiation shield assembly of any one of the claims above, comprising sixth shielding means to block radiation from the source in a fourth approximately vertical plane that is approximately parallel to the first approximately vertical plane, wherein the sixth shielding means is secured to the first shielding means, wherein the sixth shielding means is selected from the group consisting of: a generally planar shield, a flexible drape, and an extension of the first shielding means.
 28. The radiation shield assembly of any one of the claims above, wherein the first and the second shielding means are configured to rotate relative to one another over an arc of at least about 90°.
 29. The radiation shield assembly of any one of the claims above, wherein the first and the second shielding means are configured to rotate relative to one another over an arc of up to about 180°.
 30. The radiation shield assembly of any one of the claims above, wherein the first and the second shielding means are configured to rotate relative to one another over an arc of from about 0-180°.
 31. The radiation shield assembly of any one of the claims above, wherein the supporting means comprises an approximately vertical mast.
 32. The radiation shield assembly of any one of the claims above, wherein the supporting means is capable of supporting about the entire weight of the radiation shield assembly.
 33. The radiation shield assembly of any one of the claims above, wherein the supporting means is capable of supporting the entire weight of the radiation shield assembly.
 34. The radiation shield assembly of any one of the claims above, wherein in operating the supporting means supports the entire weight of the radiation shield assembly.

35. The radiation shield assembly of any one of the claims above, wherein the first shielding means and the third shielding means are configured to translate together vertically.
36. The radiation shield assembly of any one of the claims above, wherein the first shielding means and the third shielding means are configured to translate together along the support means.
37. The radiation shield assembly of any one of the claims above, wherein the first shielding means is configured to translate along the approximately vertical axis such that in a first position a top edge of the first shielding means is at least about the height of an adult human above the floor.
38. The radiation shield assembly of any one of the claims above, wherein the first shielding means is configured to translate along the approximately vertical axis such that in a first position a top edge of the first shielding means is at least about 2 m above the floor.
39. The radiation shield assembly of any one of the claims above, wherein the first shielding means has a height of at least about the distance from the upper surface of an operating table to an average human's full height.
40. The radiation shield assembly of any one of the claims above, wherein the first shielding means has a height of at least about the distance from the upper surface of an operating table to a height of 2 m from the floor when said operating table is on the floor.
41. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 0.5 mm lead equivalent.
42. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 0.5 mm lead equivalent.
43. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 1 mm lead equivalent.
44. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 1 mm lead equivalent.
45. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 1.5 mm lead equivalent.
46. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 1.5 mm lead equivalent.
47. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 2 mm lead equivalent.
48. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 2 mm lead equivalent.
49. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 3 mm lead equivalent.
50. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 3 mm lead equivalent.
51. The radiation shield assembly of any one of the claims above, wherein at least one of the first, second, third, fourth, or fifth shielding means has a radiopacity of at least 3.3 mm lead equivalent.

52. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means have a radiopacity of at least 3.3 mm lead equivalent.
53. The radiation shield assembly of any one of the claims above, wherein at least one of the first through sixth shielding means reduce radiation exposure by at least 85% when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
54. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means reduce radiation exposure by at least 85% when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
55. The radiation shield assembly of any one of the claims above, wherein at least one of the first through sixth shielding means reduce radiation exposure to below 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
56. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means reduce radiation exposure to below 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
57. The radiation shield assembly of any one of the claims above, wherein at least one of the first through sixth shielding means reduce radiation exposure to no more than about 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
58. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means reduce radiation exposure to no more than about 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
59. The radiation shield assembly of any one of the claims above, comprising a flexible radiopaque member positioned to at least partially cover the appendage opening and configured to allow the human appendage to pass through said appendage opening.
60. The radiation shield assembly of any one of the claims above, comprising a flexible radiopaque member positioned to at least partially cover the appendage opening and configured to allow the human appendage to pass through said appendage opening, wherein the flexible radiopaque member is selected from the group consisting of: a curtain, leaves of an iris port, and a sheath.
61. The radiation shield assembly of any one of the claims above, wherein the second shielding means and the fourth shielding means are configured to translate together along the support means.
62. The radiation shield assembly of any one of the claims above, comprising a means for raising and lowering at least one of the first shielding means and the third shielding means along the support means.
63. The radiation shield assembly of any one of the claims above, comprising means for raising and lowering the first shielding means and the second shielding means along the support means independently of one another.
64. The radiation shield assembly of any one of the claims above, comprising means for raising and lowering the first shielding means and the second shielding means along the support means.
65. The radiation shield assembly of any one of the claims above, wherein the means for raising and lowering is selected from the group consisting of: an assist mechanism, a counterweight system, an electric motor, a hydraulic system, a pneumatic system, and a manual system.

66. The radiation shield assembly of any one of the claims above, wherein the support means comprises a mast supported by a floor stand.
67. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom.
68. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the mast is capable of rotating about the longitudinal axis of the overhead boom.
69. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the mast is capable of pivoting relative to the overhead boom.
70. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the mast is capable of translating along the longitudinal axis of the overhead boom.
71. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the overhead boom is supported by a second mast.
72. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the overhead boom is supported by a second mast, and wherein the second mast is supported by a wall- or ceiling-mounted rail, and wherein the second mast is capable of translating along the wall- or ceiling-mounted rail.
73. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the overhead boom is supported by a second mast, and wherein the second mast is supported by a wall- or ceiling-mounted swinging arm.
74. The radiation shield assembly of any one of the claims above, wherein the support means is a mast that is suspended by an overhead boom, wherein the overhead boom is supported by a second mast, and wherein the second mast is supported by a swinging arm that is in turn supported by a wall- or ceiling-mounted rail, and wherein the swinging arm is capable of translating along the wall- or ceiling-mounted rail.
75. The radiation shield assembly of any one of the claims above, wherein at least one of the first through sixth shielding means is transparent to visible light.
76. The radiation shield assembly of any one of the claims above, wherein the first through sixth shielding means are transparent to visible light.
77. The radiation shield assembly of any one of the claims above, wherein the supporting means comprises a support arm constructed to support at least the majority of the weight of the radiation shield assembly.
78. The radiation shield assembly of any one of the claims above, wherein the first shielding means is a first vertical shield.
79. The radiation shield assembly of any one of the claims above, wherein the third shielding means is a first approximately horizontal shield.
80. The radiation shield assembly of any one of the claims above, wherein the second shielding means is a second vertical shield.

81. The radiation shield assembly of any one of the claims above, wherein the fourth shielding means is a second approximately horizontal shield.
82. The radiation shield assembly of any one of the claims above, wherein the fifth shielding means is a lower vertical shield.
83. The radiation shield assembly of any one of the claims above, wherein at least one the first through fifth shielding means is generally planar.
84. The radiation shield assembly of any one of the claims above, wherein:
- (a) the first shielding means is a first vertical shield;
 - (b) the third shielding means is a first approximately horizontal shield;
 - (c) the second shielding means is a second vertical shield;
 - (d) the fourth shielding means is a second approximately horizontal shield; and
 - (e) the fifth shielding means is a lower vertical shield.
85. A radiation shield assembly, configured to block radiation emanating from a radiation source, the assembly comprising:
- (a) a support arm constructed to support at least the majority of the weight of the shield assembly, the support arm having a longitudinal axis;
 - (b) a first radiopaque vertical shield fastened to the support arm, and having an opening proximate to a lower end dimensioned to admit a human appendage;
 - (c) a second radiopaque vertical shield; and
 - (d) a base supporting the support arm
- wherein the support arm is configured to simultaneously translate said first and second radiopaque vertical shields relative to said base along an axis that is approximately parallel to the longitudinal axis of the support arm.
86. The radiation shield assembly of claim 85, wherein the support arm comprises an outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve, and wherein the inner and outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously.
87. The radiation shield assembly of any one of claims 85-86, wherein the support arm comprises an outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve, and comprising an actuator disposed in said outer and inner sleeves and connected at opposite sides to said outer and inner sleeves.
88. The radiation shield assembly of any one of claims 85-87, wherein the support arm comprises a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve, and wherein the first inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously; and wherein the support arm comprises a second inner sleeve dimensioned to fit at least partially inside the other end of the outer sleeve.
89. The radiation shield assembly of any one of claims 85-88, wherein the support arm comprises a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve, and wherein the first inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously; and wherein the support arm comprises a second inner sleeve dimensioned to fit at least

partially inside the other end of the outer sleeve; and wherein the second inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate independently.

90. The radiation shield assembly of any one of claims 85-89, wherein the support arm comprises: a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve; a second inner sleeve dimensioned to fit at least partially inside the other end of the outer sleeve; a first actuator disposed in said first outer and first inner sleeves and connected at opposite sides to said first outer sleeve and said first inner sleeve; and a second actuator disposed in said first outer and second inner sleeves and connected at opposite sides to the first outer sleeve and the second inner sleeve.

91. *The radiation shield assembly of claim 90, wherein one or both of the first actuator and the second actuator is a linear actuator.*

92. A radiation shield assembly, configured to block radiation emanating from a radiation source, the assembly comprising:

- (a) a support arm constructed to support at least the majority of the weight of the shield assembly, the support arm having a longitudinal axis;
- (b) a first radiopaque vertical shield fastened to the support arm, and having an opening proximate to a lower end dimensioned to admit a human appendage;
- (c) a second radiopaque vertical shield;
- (d) a base supporting the support arm;
- (e) a plurality of wheels supporting said floor stand base; and
- (f) a plurality of means for adjusting the positions of said wheels.

93. The radiation shield assembly of claim 92, said means for adjusting comprising a plurality of arms adjustably connected to said floor stand base, wherein at least one of said plurality of wheels is secured to one of said arms.

94. The radiation shield assembly of claim 93, wherein a hinge rotatably connects said plurality of arms to said floor stand base.

95. The radiation shield assembly of any one of claims 92-94, wherein each means for adjusting comprises a clamp to temporarily lock the position of said arm relative to said floor stand base.

96. The radiation shield assembly of any one of claims 92-95, wherein said plurality of arms are capable of rotating at least about 30° relative to said floor stand base.

97. The radiation shield assembly of any one of claims 92-96, wherein each means for adjusting includes a stop for preventing rotation of said arms past said stop.

98. The radiation shield assembly of any one of claims 92-97, wherein said plurality of wheels are caster wheels.

99. *The radiation shield assembly of any one of claims 92-98, wherein at least one of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; and a pivot shaft within the pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft.*

100. *The radiation shield assembly of any one of claims 92-99, wherein each of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; and a pivot shaft within the pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft.*

101. The radiation shield assembly of any one of claims 92-100, wherein the means for adjusting the positions of said wheels comprises a locking mechanism configured to lock the wheels in a particular position.
102. The radiation shield assembly of any one of claims 92-101, wherein the means for adjusting the positions of said wheels comprises a locking mechanism, said locking mechanism comprising a locking collar and a locking knob configured to tighten and loosen the locking collar.
103. The radiation shield assembly of any one of claims 92-102, wherein each of the plurality of means for adjusting the positions of said wheels comprises: a pivot linkage connected to an arm member; a pivot shaft within the pivot linkage configured to permit the arm member to pivot about the axis of the pivot shaft; a locking collar 460 around the pivot shaft; and a locking knob configured to tighten and loosen the locking collar 460 to lock and unlock the wheels in a particular position.
104. The radiation shield assembly of any one of claims 85-103, comprising a first approximately horizontal shield connected to the first vertical shield so as to translate and rotate with the first vertical shield, and positioned to block radiation emanating from the opening in the first vertical shield.
105. The radiation shield assembly of any one of claims 85-93, comprising a second approximately horizontal shield connected to the second vertical shield so as to translate and rotate with the second vertical shield.
106. The radiation shield assembly of any one of claims 85-105, comprising a lower vertical shield connected to the second horizontal shield so as to translate and rotate with the second horizontal shield and the second vertical shield, the lower shield being approximately orthogonal to the second vertical shield and the second horizontal shield.
107. The radiation shield assembly of any one of claims 85-106, comprising a third generally vertical shield to block radiation from the source in an approximately vertical plane that is approximately parallel to the vertical shield, wherein third generally vertical shield is secured to the first shielding means.
108. The radiation shield assembly of any one of claims 85-107, wherein the base is a floor stand comprising: a plurality of wheels supporting said floor stand, wherein the positions of said wheels are adjustable.
109. The radiation shield assembly of claim 108, comprising a plurality of arms adjustably connected to said floor stand base, wherein at least one of said plurality of wheels is secured to one of said arms.
110. The radiation shield assembly of any one of claims 108-109, wherein a hinge rotatably connects said plurality of arms to said floor stand base.
111. The radiation shield assembly of any one of claims 108-110, comprising a clamp configured to temporarily lock the position of said arm relative to said floor stand base.
112. The radiation shield assembly of any one of claims 108-111, comprising a plurality of arms capable of rotating at least about 30° relative to said floor stand base.
113. The radiation shield assembly of any one of claims 108-112, comprising a stop for preventing rotation of said arms past said stop.
114. The radiation shield assembly of any one of claims 108-113, wherein said plurality of wheels are caster wheels.
115. The radiation shield assembly of any one of the claims above, comprising a sixth shielding means to block radiation from the source in a fourth approximately vertical plane that is approximately parallel to the first approximately vertical plane, wherein the sixth shielding means is secured to the first shielding means, wherein

the third generally vertical shield is selected from the group consisting of: a solid shield, a generally planar solid shield, a flexible drape, and an extension of the first vertical shield.

116.A radiation shield assembly, configured to block radiation emanating from a radiation source, the assembly comprising:

- (a) a support arm constructed to support at least the majority of the weight of the shield assembly, the support arm having a longitudinal axis;
- (b) a first vertical shield fastened to the support arm via a first radiopaque joint; and
- (c) a second vertical shield translatably and rotationally connected to the support arm via a second radiopaque joint to rotate about an axis that is approximately parallel to the longitudinal axis of the support arm and to translate along the axis simultaneously with the first vertical shield.

117.The radiation shield assembly of claim 116, comprising a lower vertical shield connected to the second vertical shield so as to translate and rotate with the second vertical shield, the lower shield being approximately orthogonal to the second vertical shield and the second horizontal shield.

118. The radiation shield assembly of any one of claims 116-117, wherein the support arm comprises an outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve, and wherein the inner and outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously.

119. The radiation shield assembly of any one of claims 116-118, wherein the support arm comprises an outer sleeve and an inner sleeve dimensioned to fit at least partially inside one end of said outer sleeve, and comprising an actuator disposed in said outer and inner sleeves and connected at opposite sides to said outer and inner sleeves.

120. The radiation shield assembly of any one of claims 116-119, wherein the support arm comprises a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve, and wherein the first inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously; and wherein the support arm comprises a second inner sleeve dimensioned to fit at least partially inside the other end of the outer sleeve.

121. The radiation shield assembly of any one of claims 116-120, wherein the support arm comprises a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve, and wherein the first inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate simultaneously; and wherein the support arm comprises a second inner sleeve dimensioned to fit at least partially inside the other end of the outer sleeve; and wherein the second inner and first outer sleeves slide relative to one another to allow the first and second radiopaque vertical shields to translate independently.

122. The radiation shield assembly of any one of claims 116-121, wherein the support arm comprises: a first outer sleeve and a first inner sleeve dimensioned to fit at least partially inside one end of first outer sleeve; a second inner sleeve dimensioned to fit at least partially inside the other end of the outer sleeve; a first actuator disposed in said first outer and first inner sleeves and connected at opposite sides to said first outer sleeve and said first inner sleeve; and a second actuator disposed in said first outer and second inner sleeves and connected at opposite sides to the first outer sleeve and the second inner sleeve.

123. The radiation shield assembly of claim 122, wherein one or both of the first actuator and the second actuator is a linear actuator.

124. A system for shielding a user from a bottom-mounted X-ray projector while said user attends to a prostrate patient positioned above the X-ray projector, the system comprising:

- (a) a table constructed to support the patient, the table having a longitudinal axis and a transverse axis;
- (b) the X-ray projector positioned below the table;
- (c) an image intensifier positioned above the table to receive X-rays projected from the X-ray projector;
- (d) a radiopaque curtain shield extending downwardly from the table on at least a first side of the table; and
- (e) the radiation shield assembly of any one of claims 1-82;

wherein the second shielding means is configured to be rotated about its axis to be approximately orthogonal to the longitudinal axis of the table or to be approximately parallel to the longitudinal axis of the table.

125. The system of claim 124, wherein the first shielding means comprises: an opening positioned above the table to allow the patient's arm to pass through the opening; and third shielding means positioned above the opening so as to block radiation emitted through the opening.

126. The system of any one of claims 124-125, wherein the shield assembly comprises a fourth shielding means connected to the second shielding means and positioned above the table.

127. The system of any one of claims 124-126, wherein the shield assembly comprises a fourth shielding means connected to the second shielding means and positioned above the table; and wherein the shield assembly comprises a fifth shielding means extending from the second horizontal shield to below the table.

128. A system for shielding a user from a bottom-mounted X-ray projector while said user attends to a prostrate patient positioned above the X-ray projector, the system comprising:

- (a) a table constructed to support the patient, the table having a longitudinal axis and a transverse axis;
- (b) the X-ray projector positioned below the table;
- (c) an image intensifier positioned above the table to receive X-rays projected from the X-ray projector;
- (d) a radiopaque curtain shield extending downwardly from the table on at least a first side of the table; and
- (e) the radiation shield assembly of any one of claims 85-123;

wherein the second vertical shield is configured to be rotated about its axis to be approximately orthogonal to the longitudinal axis of the table or to be approximately parallel to the longitudinal axis of the table.

129. The system of claim 128, wherein the first vertical shield comprises: an opening positioned above the table to allow the patient's arm to pass through the opening; and a first generally horizontal shield positioned above the opening so as to block radiation emitted through the opening.

130. The system of any one of claims 128-129, wherein the shield assembly comprises a second generally horizontal shield connected to the second vertical shield and positioned above the table.

131. The system of any one of claims 128-89, wherein the shield assembly comprises a second generally horizontal shield connected to the second vertical shield and positioned above the table; and wherein the shield assembly comprises a lower vertical shield extending from the second horizontal shield to below the table.

132. The radiation shield assembly or system of any one of claims 84-131, wherein the first and the second vertical shields are configured to rotate relative to one another over an arc of at least about 90°.

133. The radiation shield assembly or system of any one of claims 84-132, wherein the first and the second vertical shields are configured to rotate relative to one another over an arc of up to about 180°.
134. The radiation shield assembly or system of any one of claims 84-133, wherein the first and the second vertical shields are configured to rotate relative to one another over an arc of about 0-180°.
135. The radiation shield assembly or system of any one of claims 84-134, wherein the support arm comprises an approximately vertical mast.
136. The radiation shield assembly or system of any one of claims 84-135, wherein the support arm is capable of supporting about the entire weight of the radiation shield assembly.
137. The radiation shield assembly or system of any one of claims 84-136, wherein the support arm is capable of supporting the entire weight of the radiation shield assembly.
138. The radiation shield assembly or system of any one of claims 84-137, wherein in operation the support arm supports the entire weight of the radiation shield assembly.
139. The radiation shield assembly or system of any one of claims 84-138, wherein the first vertical shield is configured to translate vertically.
140. The radiation shield assembly or system of any one of claims 84-139, wherein the first vertical shield and the first approximately horizontal shield are configured to translate together vertically.
141. The radiation shield assembly or system of any one of claims 84-140, wherein the first vertical shield is configured to translate along the support arm.
142. The radiation shield assembly or system of any one of claims 84-141, wherein the first vertical shield and the first approximately horizontal shield are configured to translate together along the support arm.
143. The radiation shield assembly or system of any one of claims 84-142, wherein the first vertical shield is configured to translate along the approximately vertical axis such that in a first position a top edge of the first vertical shield is at least about the height of an adult human above the floor.
144. The radiation shield assembly or system of any one of claims 84-143, wherein the first vertical shield is configured to translate along an approximately vertical axis such that in a first position a top edge of the first vertical shield is at least about 2 m above the floor.
145. The radiation shield assembly or system of any one of claims 84-144, wherein the first vertical shield has a height of at least about the distance from the upper surface of an operating table to an average human's full height.
146. The radiation shield assembly or system of any one of claims 84-145, wherein the first vertical shield has a height of at least about the distance from the upper surface of an operating table to a height of 2 m from the floor when said operating table is on the floor.
147. The radiation shield assembly or system of any one of claims 84-146, wherein at least one of said shields has a radiopacity of at least 0.5 mm lead equivalent.
148. The radiation shield assembly or system of any one of claims 84-147, wherein all of said shields have a radiopacity of at least 0.5 mm lead equivalent.
149. The radiation shield assembly or system of any one of claims 84-148, wherein at least one of said shields has a radiopacity of at least 1 mm lead equivalent.

150. The radiation shield assembly or system of any one of claims 84-149, wherein all of said shields have a radiopacity of at least 1 mm lead equivalent.
151. The radiation shield assembly or system of any one of claims 84-150, wherein at least one of said shields has a radiopacity of at least 1.5 mm lead equivalent.
152. The radiation shield assembly or system of any one of claims 84-151, wherein all of said shields have a radiopacity of at least 1.5 mm lead equivalent.
153. The radiation shield assembly or system of any one of claims 84-152, wherein at least one of said shields has a radiopacity of at least 2 mm lead equivalent.
154. The radiation shield assembly or system of any one of claims 84-153, wherein all of said shields have a radiopacity of at least 2 mm lead equivalent.
155. The radiation shield assembly or system of any one of claims 84-154, wherein at least one of said shields has a radiopacity of at least 3 mm lead equivalent.
156. The radiation shield assembly or system of any one of claims 84-155, wherein all of said shields have a radiopacity of at least 3 mm lead equivalent.
157. The radiation shield assembly or system of any one of claims 84-156, wherein at least one of said shields has a radiopacity of at least 3.3 mm lead equivalent.
158. The radiation shield assembly or system of any one of claims 84-157, wherein all of said shields have a radiopacity of at least 3.3 mm lead equivalent.
159. The radiation shield assembly or system of any one of claims 84-158, wherein at least one of said shields reduce radiation exposure by at least 85% when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
160. The radiation shield assembly or system of any one of claims 84-159, wherein all of said shields reduce radiation exposure by at least 85% when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
161. The radiation shield assembly or system of any one of claims 84-160, wherein at least one of said shields reduce radiation exposure to below 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
162. The radiation shield assembly or system of any one of claims 84-161, wherein all of said shields reduce radiation exposure to below 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
163. The radiation shield assembly or system of any one of claims 84-162, wherein at least one of said shields reduce radiation exposure to no more than about 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
164. The radiation shield assembly or system of any one of claims 84-163, wherein all of said shields reduce radiation exposure to no more than about 2.5 mR/hr when measured by the Modified ASTM F3094/IEC 61331-1 Protocol.
165. The radiation shield assembly or system of any one of claims 84-164, wherein the second vertical shield and the second approximately horizontal shield are configured to translate together along the support arm.

166. The radiation shield assembly or system of any one of claims 84-165, comprising a flexible radiopaque member positioned to at least partially cover the appendage opening and configured to allow the human appendage to pass through said appendage opening.
167. The radiation shield assembly or system of any one of claims 84-166, comprising a flexible radiopaque member positioned to at least partially cover the appendage opening and configured to allow the human appendage to pass through said appendage opening, and wherein the flexible radiopaque member is selected from the group consisting of: a curtain, leaves of an iris port, and a sheath.
168. The radiation shield assembly or system of any one of claims 84-167, comprising a means for raising and lowering at least one of the first vertical shield and the first approximately horizontal shield along the support arm.
169. The radiation shield assembly or system of any one of claims 84-168, comprising a means for raising and lowering at least one of the first vertical shield and the first approximately horizontal shield along the support arm, wherein the means for raising and lowering is selected from the group consisting of: an assist mechanism, a counterweight system, an electric motor, a hydraulic system, a pneumatic system, and a manual system.
170. The radiation shield assembly or system of any one of claims 84-169, wherein the support arm comprises a mast supported by a floor stand.
171. The radiation shield assembly or system of any one of claims 84-170, wherein the support arm is a mast that is suspended by an overhead boom.
172. The radiation shield assembly or system of any one of claims 84-171, wherein the support arm is a mast that is suspended by an overhead boom, and wherein the mast is capable of rotating about the longitudinal axis of the overhead boom.
173. The radiation shield assembly or system of any one of claims 84-172, wherein the support arm is a mast that is suspended by an overhead boom, and wherein the overhead boom is supported by a second mast.
174. The radiation shield assembly or system of any one of claims 84-173, wherein the support arm is a mast that is suspended by an overhead boom, and wherein the second mast is supported by a wall- or ceiling-mounted rail, and wherein the second mast is capable of translating along the wall- or ceiling-mounted rail.
175. The radiation shield assembly or system of any one of claims 84-174, wherein the support arm is a mast that is suspended by an overhead boom, and wherein the second mast is supported by a wall- or ceiling-mounted swinging arm.
176. The radiation shield assembly or system of any one of claims 84-175, wherein the support arm is a mast that is suspended by an overhead boom, and wherein the second mast is supported by a swinging arm that is in turn supported by a wall- or ceiling-mounted rail, and wherein the swinging arm is capable of translating along the wall- or ceiling-mounted rail.
177. The radiation shield assembly or system of any one of claims 84-176, wherein at least one of the shields is approximately planar, said at least one of the shields selected from: the first vertical shield, the second vertical shield, the lower vertical shield, the first horizontal shield, and the second horizontal shield.

178. The radiation shield assembly or system of any one of claims 84-177, wherein all of the first vertical shield, the second vertical shield, the lower vertical shield, the first horizontal shield, and the second horizontal shield are approximately planar.
179. The radiation shield assembly or system of any one of claims 84-178, wherein at least one of said shields is transparent to visible light.
180. The radiation shield assembly or system of any one of claims 84-179, wherein all of said shields are transparent to visible light.
181. A radiography method comprising:
 - (a) positioning the radiation shield assembly or system of any one of claims 1-180 between a patient and a user, such that an appendage of the patient extends through an appendage opening in the shield assembly;
 - (b) inserting a medical device into vasculature of the appendage; and
 - (c) irradiating the patient using a radiation generator positioned such that radiation passes at least partially through the patient while being blocked from reaching the user by the shield assembly.