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(54) **ELECTROMAGNETIC RADIATION THERAPY**

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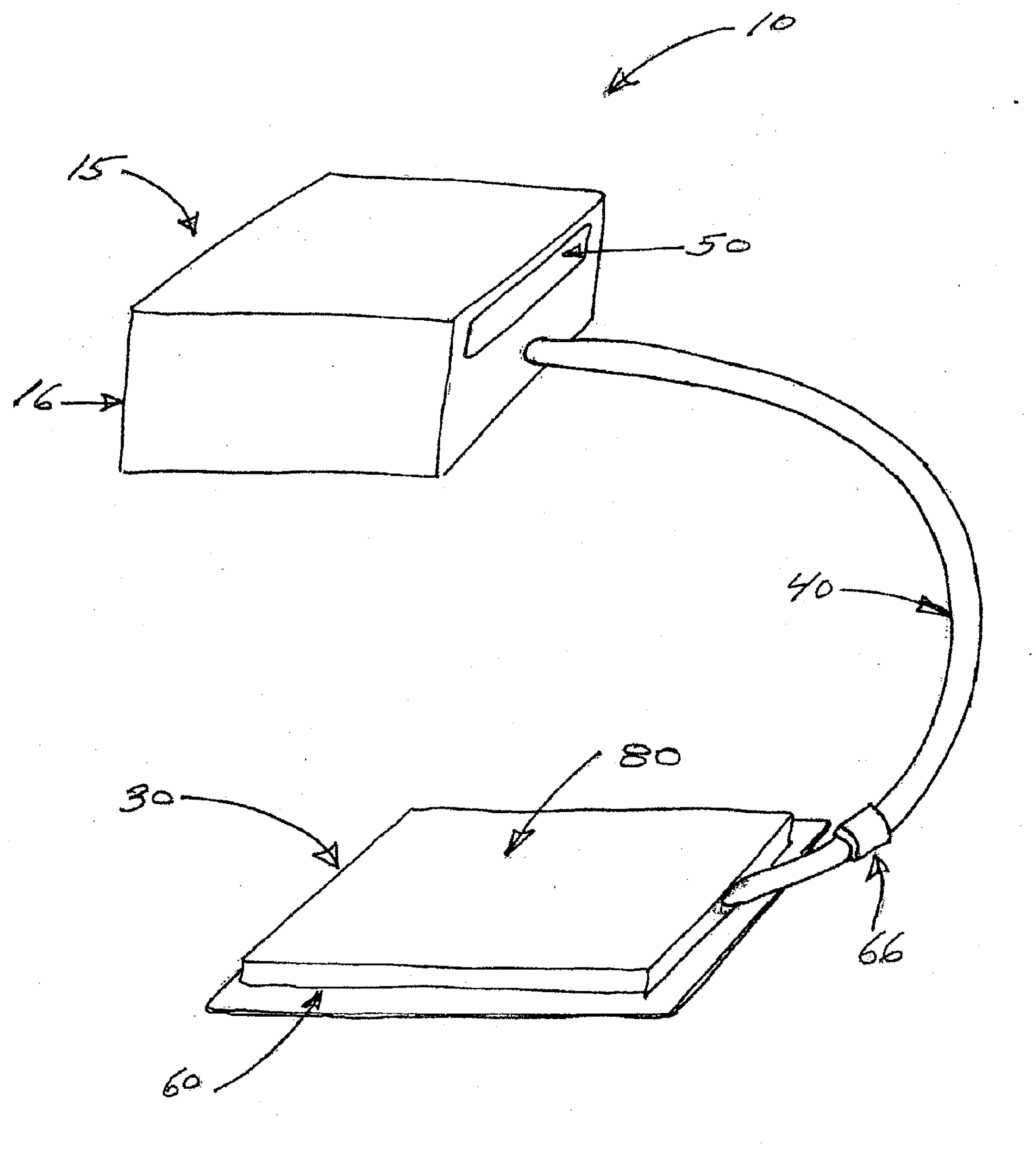
(57) **ABSTRACT**

Apparatuses and methods for the prevention, reduction, or elimination of tissue injury by the application of electromagnetic energy. The apparatuses and methods have application for use in various tissues within diverse regions of the body, including for the prevention, reduction, or elimination of acute kidney injury, kidney failure, and contrast-induced nephropathy.



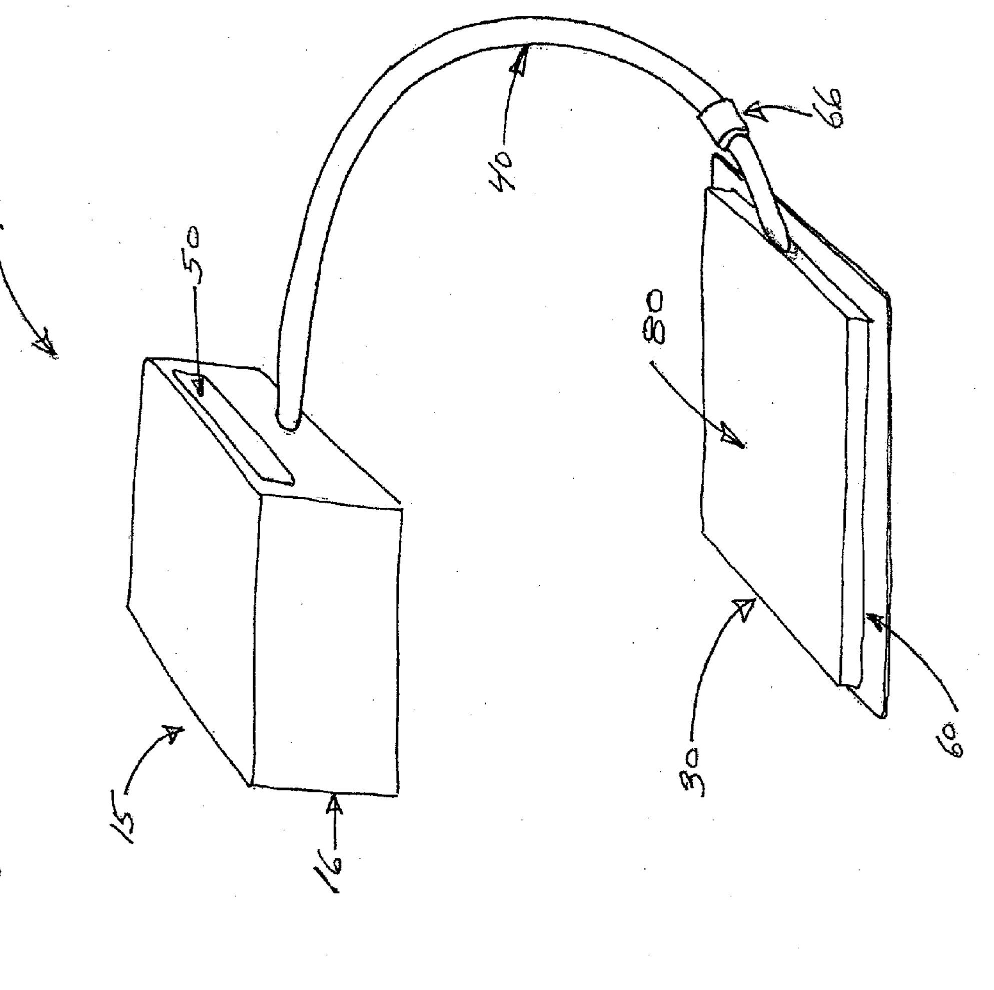
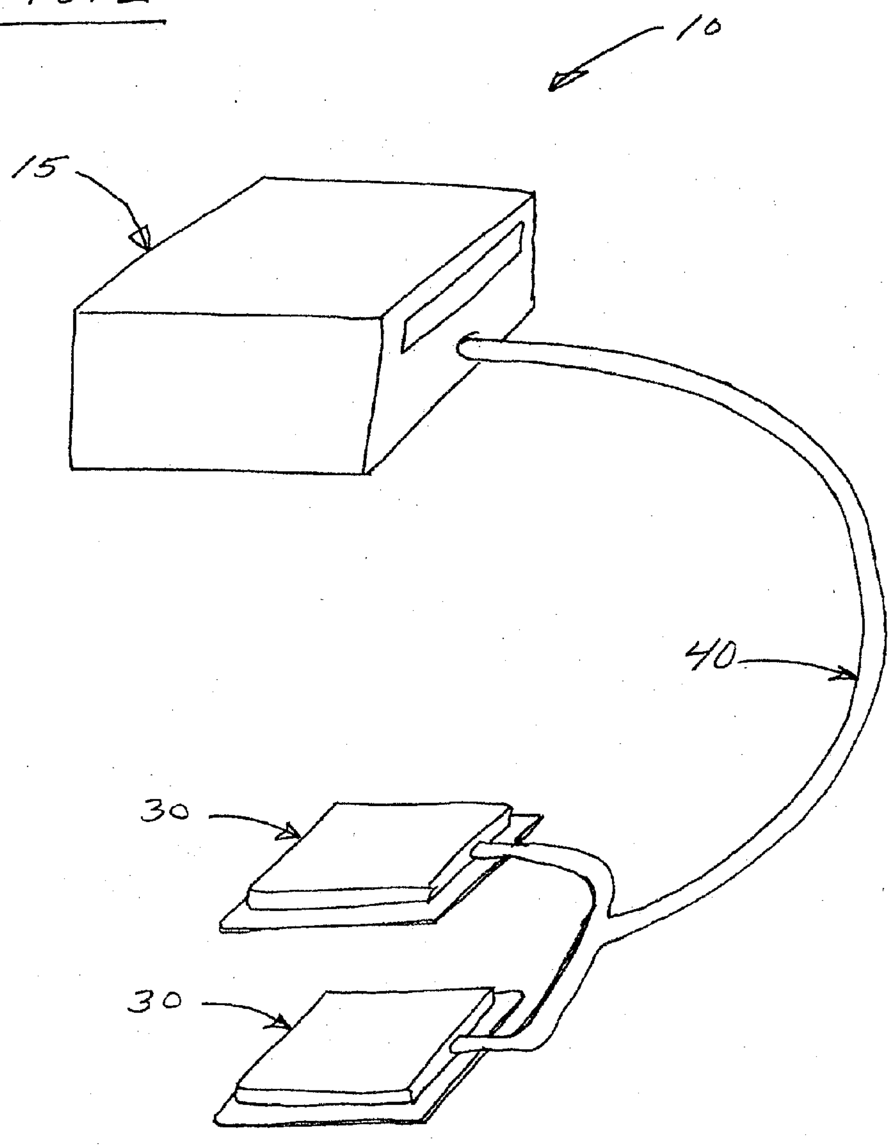


FIG. 1

FIG. 2



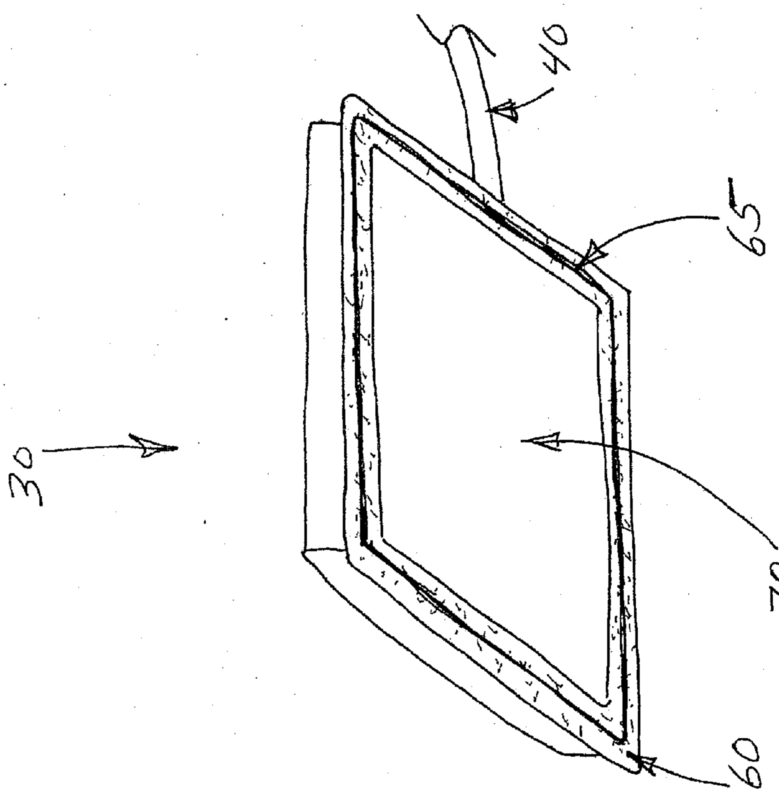


FIG. 3

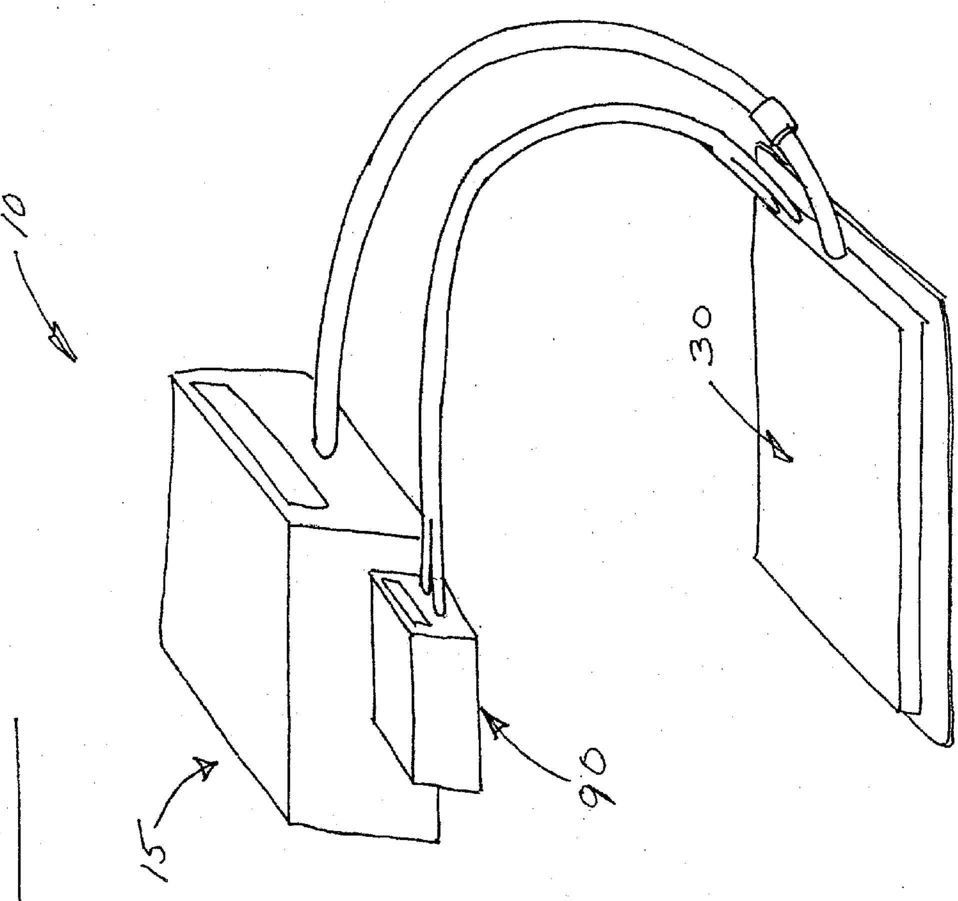


FIG. 4

FIG. 5

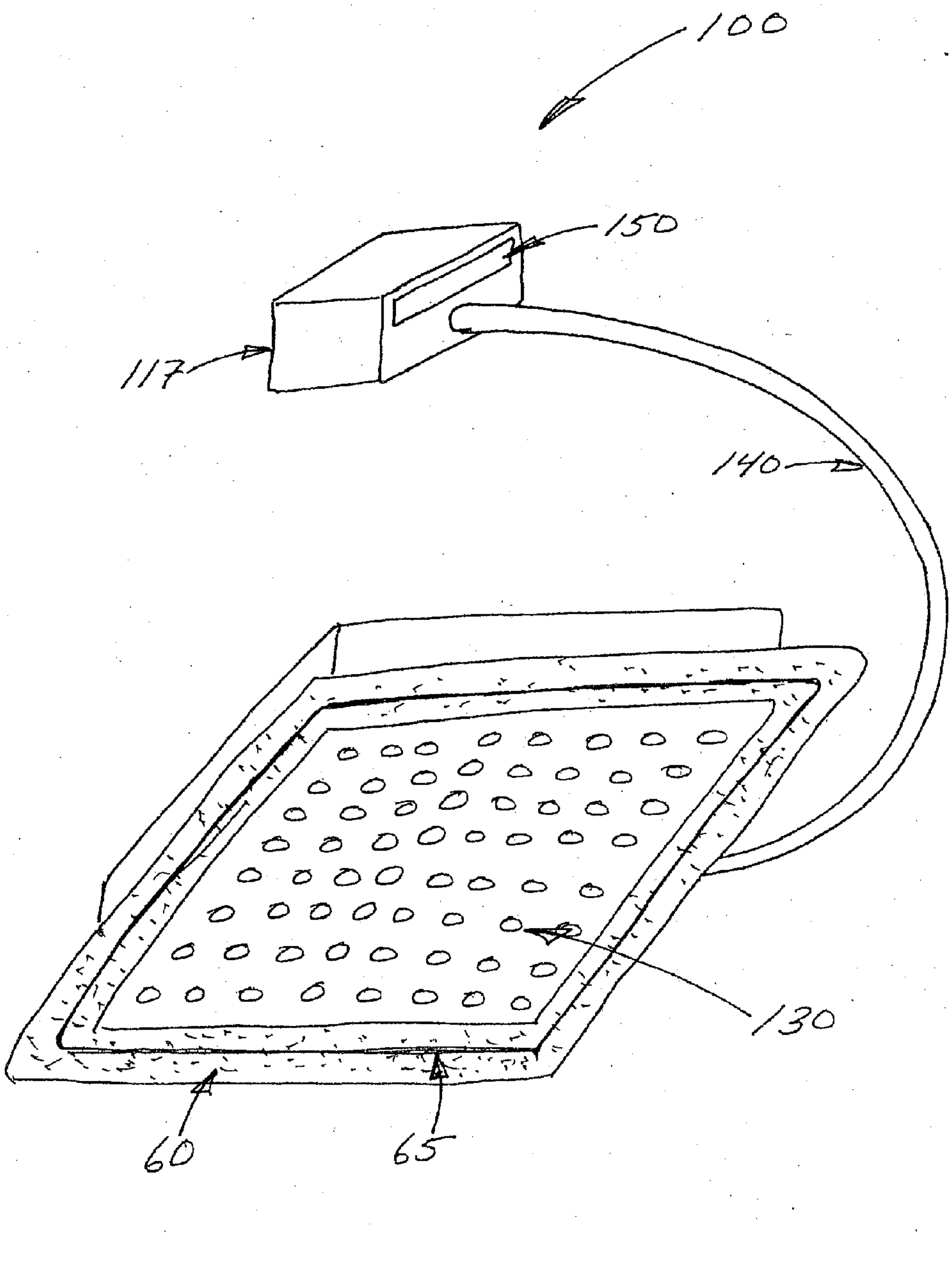
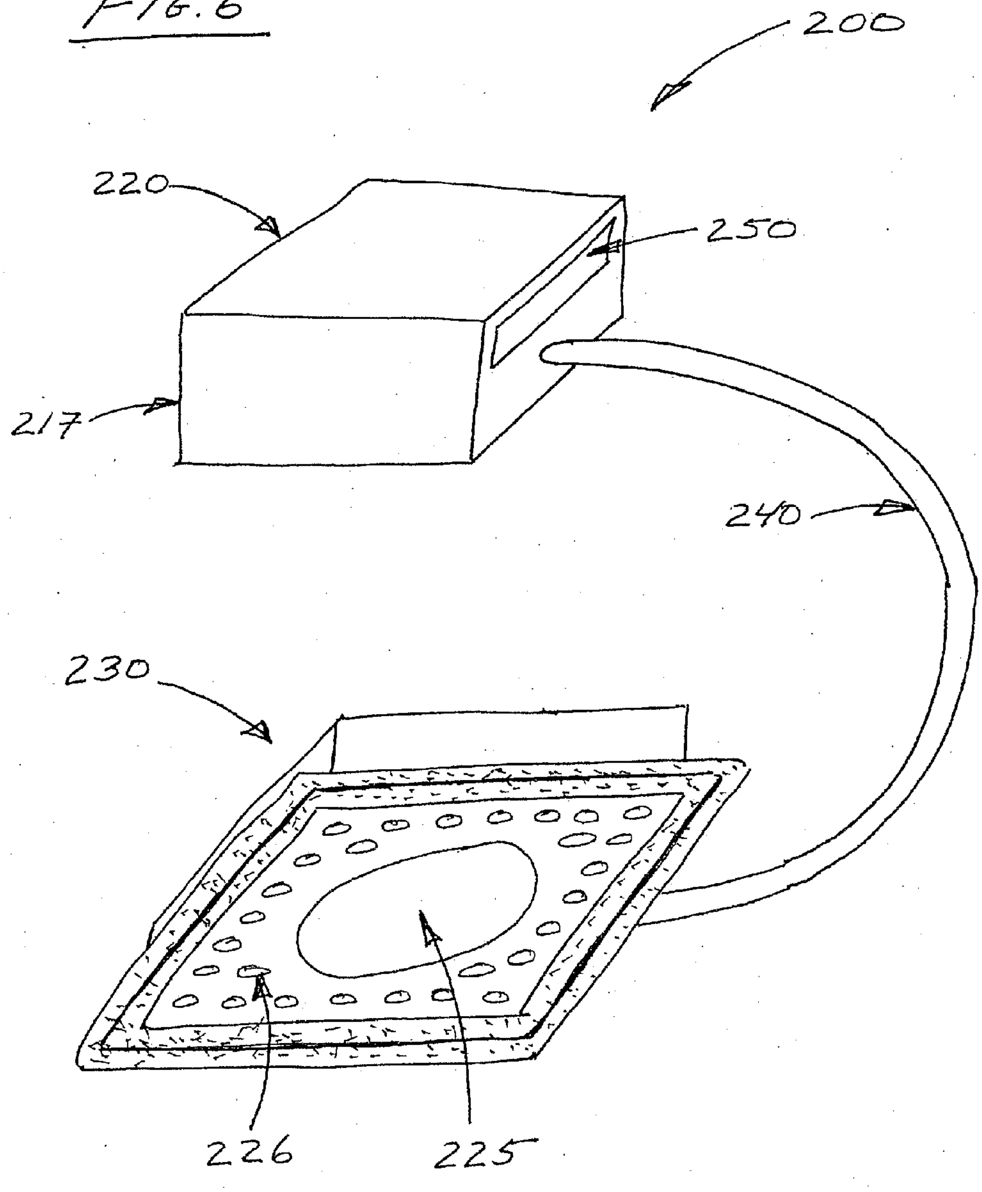


FIG. 6



ELECTROMAGNETIC RADIATION THERAPY

RELATED INFORMATION

[0001] This application claims priority to U.S. provisional patent application Ser. No. 61/308,620 filed on Feb. 25, 2010, which is fully incorporated herein by reference.

FIELD OF THE INVENTION

[0002] This invention relates to the use of electromagnetic radiation for the prevention and treatment of injury to and disorders of biological issues, and more specifically to novel apparatuses and methods for the prevention and treatment of kidney injury and failure.

BACKGROUND OF THE INVENTION

[0003] Acute renal failure or acute kidney injury is characterized by a rapid reduction in renal function. The causes are numerous and are commonly categorized as pre-renal, renal or intrinsic, and post-renal.

[0004] Pre-renal causes are characterized by inadequate blood perfusion to the kidneys. These include volume depletion; examples include hemorrhage, loss of intravascular fluid due to ascities, peritonitis, and burns; low cardiac output due to cardiomyopathy, myocardial infarction, cardiac tamponade, and pulmonary embolism, among others; low systemic vascular resistance due to shock, liver failure, or antihypertensive drugs; increased vascular resistance caused by hypercalcemia, anaphylaxis, anesthetics, renal artery obstruction, renal vein thrombosis, sepsis, and hepatorenal syndrome; and decreased efferent arteriolar tone.

[0005] Renal causes involve intrinsic renal disease or damage to the kidney itself, most commonly from renal ischemia and nephrotoxins. Causes include acute tubular injury due to ischemia; from surgery (blood loss, blood flow reduction-cross clamping), hemorrhage, arterial or venous obstruction, and cyclosporine, tacrolimus, and amphotericin B; and toxins, such as radiopaque contrast agents which lead to contrast-induced nephropathy, Aminoglycosides, amphotericin B, foscarnet, ethylene glycol, hemoglobinuria, myoglobinuria, ifosfamide, and heavy metals.

[0006] Acute glomerulonephritis; ANCA associated, anti-GBM glomerulonephritis, and immune complex; acute tubulointerstitial nephritis due to drug reactions, pyelonephritis, and papillary necrosis; acute vascular nephropathy from vasculitis, malignant hypertension, thrombotic microangiopathies, scleroderma, and atheroembolism; and infiltrative diseases such as lymphoma, sarcoidosis, and leukemia constitute renal causes as well.

[0007] Post-renal causes are due to various types of obstruction within the urinary system. Obstruction can also occur within the tubules when crystalline or proteinaceous material precipitates. Examples include: renal calculi; retroperitoneal fibrosis; prostatic hypertrophy; carcinoma and cervical carcinoma; urethral stricture; and bladder, pelvic, and/or retroperitoneal neoplasm.

[0008] The primary treatment for acute kidney injury is correcting the fluid and electrolyte balances from either fluid depletion or fluid overload; treatment of the underlying medical condition and restoration of blood perfusion to the kidneys; and the discontinuation of potentially deleterious medications.

[0009] Current strategies for the prevention of acute kidney injury are: maintaining normal fluid balance, blood volume, and blood pressure in patients with trauma, burns, or major hemorrhage and in those undergoing major surgery; in cases requiring the use of a contrast agent, minimizing the volume of contrast agent, using nonionic and low-osmolar or iso-osmolar contrast agents, and pretreating with normal saline; and withholding potentially nephrotoxic drugs, including aminoglycoside antibiotics, anti-rejection medications, and nonsteroidal anti-inflammatory drugs.

[0010] Notwithstanding the current therapies, acute kidney injury remains common in hospitalized patients and carries a poor prognosis. Non-ICU acute kidney injury carries a mortality rate of up to 10%. ICU acute kidney injury carries a mortality rate of over 50%.

[0011] Patients receiving intravascular administration of iodinated contrast media are at risk of developing contrast-induced nephropathy, the third leading cause of hospital-acquired acute kidney injury, accounting for approximately 12% of all cases. Contrast-induced nephropathy is associated with both short- and long-term adverse outcomes, including the need for renal replacement therapy, increased length of hospital stay, major cardiac adverse events, and mortality. The incidence of contrast-induced nephropathy is estimated to be 1% to 6% in the general population. However, in patient subgroups with multiple comorbidities, the risk grows to as high as 50%. Following percutaneous coronary intervention, in-hospital mortality rates have been found to be 1% in patients without contrast-induced nephropathy, approximately 7% for patients with contrast-induced nephropathy, and up to 36% for patients with contrast-induced nephropathy requiring dialysis.

[0012] Multiple pharmacologic interventions have been evaluated for the prevention of contrast-induced nephropathy, including: angiotensin II, fenoldopam, dopamine, calcium-channel blockers, endothelin antagonists, and adenosine, though none of these have been found to be beneficial. The principal intervention is extracellular volume expansion, primarily with the administration of intravenous fluid. Other pharmacologic agents, N-acetylcysteine, sodium bicarbonate, and ascorbic acid have seen mixed results in clinical trials are still under evaluation to determine if they provide a beneficial effect.

[0013] In additional to pharmacologic strategies for contrast-induced nephropathy, attempts are being made to remove blood, and with it contrast media, directly from the patient's coronary sinus with interventional catheters. Even with this invasive approach, not all the contrast media is removed and the kidneys are therefore still at risk.

[0014] Electromagnetic radiation systems of many different types are used in a wide variety of medical procedures. Some of the many types of electromagnetic radiation systems are visible light systems and infrared systems; some are intended for diagnostic purposes, such as infrared spectroscopy, and some for therapeutic purposes including chronic pain management, wound healing, cosmetic surgery, and dentistry.

[0015] Electromagnetic radiation in the red/near infrared range has been shown to modulate various biological processes such as increasing mitochondrial respiration, adenosine triphosphate synthesis, and preventing apoptosis. This effect has been applied clinically to facilitate wound healing; promote skeletal muscle regeneration and angiogenesis; and improve neurologic function in ischemic brain tissue. However, the mechanism of action in these uses is not well understood. Furthermore, the problem of nephropathy caused by contrast agents is distinct from these prior uses and is itself not well understood.

[0016] Based upon the lack of preventative strategies and the inadequacies of the currently available therapies, there remains a strong clinical need for new and improved apparatuses and methods for the prevention and treatment of kidney injury and failure, particularly such injury and failure caused by contrast agents.

SUMMARY OF THE INVENTION

[0017] One preferred embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue.

[0018] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to abdomen, to irradiate at least a portion of kidney tissue.

[0019] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, to prevent, reduce, or eliminate injury to the kidney tissue.

[0020] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue prior to kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0021] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue at least during a portion of the time of kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0022] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, at least during a portion of the time of and/or after the kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0023] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0024] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of a diagnostic procedure, to prevent, reduce, or eliminate injury to the kidney tissue.

[0025] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of an interventional procedure, to prevent, reduce, or eliminate injury to the kidney tissue.

[0026] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, concurrently or independently applying acoustic energy of at least one efficacious energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0027] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, concurrently or independently applying acoustic energy of at least one efficacious energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, to prevent, reduce, or eliminate contrast-induced nephropathy.

[0028] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, concurrently or independently applying acoustic energy of at least one efficacious energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the introduction of contrast media to the patient, to prevent, reduce, or eliminate contrast-induced nephropathy.

[0029] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, concurrently or independently applying a magnetic field of at least one efficacious field strength to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, to prevent, reduce, or eliminate injury to the kidney tissue.

[0030] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises 'introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, and administering a pharmacologic agent (e.g. hydration, volume expansion, N-acetylcysteine, sodium bicarbonate, ascorbic acid) prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0031] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of an interventional procedure, and administering a pharmacologic agent (e.g. hydration, volume expansion, N-acetylcysteine, sodium bicarbonate, ascorbic acid) prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0032] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. The electromagnetic radiation source comprising a laser and/or at least one light emitting diode.

[0033] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. Introducing the electromagnetic radiation through an element in contact with the skin.

[0034] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. Reducing thermal changes near the skin.

[0035] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. Sensing for thermal changes and modifying or ceasing delivery of the electromagnetic radiation if predetermined thermal changes are detected.

[0036] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. Sensing for electromagnetic radiation of at least one efficacious wavelength and ceasing delivery of the electromagnetic radiation if electromagnetic radiation of at least one efficacious wavelength is detected.

[0037] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. Sensing for electromagnetic radiation of at least one efficacious wavelength and ceasing delivery of the electromagnetic radiation if electromagnetic radiation of at least one efficacious wavelength is detected above a threshold level.

[0038] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, to prevent, reduce, or eliminate injury to the kidney tissue. Concurrently or independently of the delivery of electromagnetic radiation effecting a decrease in the absorption and/or blood flow and/or blood vessel diameter in at lease a portion of the area exposed to the electromagnetic radiation.

[0039] Another embodiment of the present invention provides a method for treating kidney tissue. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, to prevent, reduce, or eliminate injury to the kidney tissue. Concurrently or independently of the delivery of electromagnetic radiation effecting an increase in the transmission of the electromagnetic radiation.

[0040] In certain embodiments, the methods encompass using electromagnetic radiation having at least one wavelength of about 635 nm to about 1560 nm.

[0041] In certain embodiments, the methods encompass using electromagnetic radiation having at least one wavelength of about 635 nm to about 980 nm.

[0042] In certain embodiments, the methods encompass using electromagnetic radiation having at least one wavelength of about 700 nm to about 980 nm.

[0043] In certain embodiments, the methods encompass using electromagnetic radiation having a power density of at least 0.01 mW/cm^2 at the kidney tissue.

[0044] In certain embodiments, the methods encompass using electromagnetic radiation having an energy density of at least 0.01 J/cm^2 at the kidney tissue.

[0045] In certain embodiments, the methods encompass delivering electromagnetic radiation in at least continuous wave mode.

[0046] In certain embodiments, the methods encompass delivering electromagnetic radiation in at least pulsed wave mode.

[0047] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue.

[0048] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprising a laser and/or at least one light emitting diode as one electromagnetic radiation source.

[0049] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element in contact with the skin.

[0050] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element in contact with the skin. The element adapted to reduce thermal changes near the skin.

[0051] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises and element in contact with the skin. The element adapted to reduce the temperature near the skin at or near the region of irradiation.

[0052] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue. The apparatus further comprises a sensor for sensing thermal changes and modifying or ceasing delivery of the electromagnetic radiation if predetermined thermal changes are detected.

[0053] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element to reduce or eliminate electromagnetic radiation of at least one efficacious wavelength from being emitted in at least one undesirable direction.

[0054] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element to reduce or eliminate electromagnetic radiation of at least one efficacious wavelength from being emitted away from the patient.

[0055] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element for constraining the electromagnetic radiation of at least one efficacious wavelength being emitted between the emitting source and the patient.

[0056] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises an element for maintaining position of at least on element of the apparatus in relation to the patient.

[0057] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises a sensor to sense electromagnetic radiation of at least one efficacious wavelength.

[0058] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises a sensor to sense electromagnetic radiation of at least one efficacious wavelength. The apparatus further comprises an element or component for ceasing delivery of the electromagnetic radiation if electromagnetic radiation of at least one efficacious wavelength is detected.

[0059] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further comprises a sensor to sense electromagnetic radiation of at least one efficacious wavelength. The apparatus further comprises an element or component for ceasing delivery of the electromagnetic radiation if electromagnetic radiation of at least one efficacious wavelength is detected above a threshold level.

[0060] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy and at least one acoustic energy source of at least one efficacious energy. The apparatus further comprising the delivery of the efficacious energies either concurrently or independently to at least a portion of kidney tissue.

[0061] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy and at least one magnetic field source of at least one efficacious field strength. The apparatus further comprising the delivery of the efficacious energies either concurrently or independently to at least a portion of kidney tissue.

[0062] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further affecting, concurrently or independently of the delivery of electromagnetic radiation, a decrease in the absorption and/or blood flow and/or blood vessel diameter in at least a portion of the area exposed to the electromagnetic radiation.

[0063] Another embodiment of the present invention provides an apparatus for treating kidney tissue. The apparatus comprises at least one electromagnetic radiation source of at least one efficacious wavelength and energy, positioned to irradiate at least a portion of kidney tissue. The apparatus further affecting, concurrently or independently of the delivery of electromagnetic radiation, an increase in the transmission of the electromagnetic radiation.

[0064] In certain embodiments, the apparatus encompasses using electromagnetic radiation having at least one wavelength of about 635 nm to about 1560 nm.

[0065] In certain embodiments, the apparatus encompasses using electromagnetic radiation having at least one wavelength of about 635 nm to about 980 nm.

[0066] In certain embodiments, the apparatus encompasses using electromagnetic radiation having at least one wavelength of about 700 nm to about 980 nm.

[0067] In certain embodiments, the apparatus encompasses using electromagnetic radiation having a power density of a power density of at least 0.01 mW/cm^2 at the kidney tissue.

[0068] In certain embodiments, the apparatus encompasses using electromagnetic radiation having an energy density of at least 0.01 J/cm^2 at the kidney tissue.

[0069] In certain embodiments, the apparatus encompasses using electromagnetic radiation in at least continuous wave mode.

[0070] In certain embodiments, the apparatus encompasses using electromagnetic radiation in at least pulsed wave mode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0071] FIG. **1** illustrates a system **10** for applying electromagnetic radiation energy for the prevention, reduction, or elimination of acute kidney injury and/or kidney failure.

[0072] FIG. **2** illustrates an embodiment of the system **10** with multiple applicators **30**.

[0073] FIG. **3** illustrates a view of the patient side of an applicator **30**.

[0074] FIG. **4** illustrates an embodiment of the system **10** with a cooling system **90**.

[0075] FIG. **5** illustrates an embodiment of a combination system **100**.

[0076] FIG. **6** illustrates an embodiment of a multiple source system **200**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0077] Apparatuses and methods will be described for the purpose of preventing, reducing, or eliminating tissue injury by the application of electromagnetic energy. The apparatuses and methods have application for use in various tissues within diverse regions of the body. According to the present invention, the electromagnetic radiation energy is desirably indicated, e.g., for the prevention, reduction, or elimination of acute kidney injury and/or kidney failure; and/or before, during, or after the acute kidney injury and/or kidney failure has begun; and/or before, during, or after a new kidney injury and/or insult has occurred, e.g. angiographic procedures, surgical procedures, contrast-enhanced imaging procedures, any introduction of contrast media to a patient, etc.

[0078] The terms "injury" or "insult" as they relate to the kidneys shall mean any tissue injury, insult, or damage resulting from any or all of the following causes: pre-renal, renal or intrinsic, and post-renal.

[0079] FIG. **1** schematically shows a compact, portable electromagnetic energy system **10** that makes it possible to apply electromagnetic energy to a patient. The system **10** enables the application of electromagnetic radiation energy to a patient at a designated treatment location. For example, the system **10** will be described herein for irradiation of the kidneys for the prevention, reduction, or elimination of acute kidney injury and/or kidney failure, understanding it is within the scope of the present invention that the system **10** may be modified for irradiation of other tissues within the body.

[0080] As FIG. **1** shows, the system **10** includes at least one electromagnetic radiation energy generating machine **15**. The system **10** also includes at least one electromagnetic radiation energy applicator **30**, which is coupled to the machine **15** via at least one interconnect **40**.

[0081] The machine **15** can be sized and shaped to provide a lightweight and portable unit suited for use in varying locations, e.g. bedside, catheterization laboratory, surgical suite, etc. The machine **15** includes a housing **16** which houses an electromagnetic radiation energy generating source **20** (not shown). The electromagnetic radiation energy is delivered to the applicator **30** by an interconnect **40**. One or more controllers **50** may also be housed within the housing **16** (but which could be external of the housing **16**, if so desired). Further desirable technical features of the applicator **30**, interconnect **40**, and controller(s) **50** will be described later.

[0082] The source **20**, may be, for example at least one light emitting diode, laser, and/or laser diode, or multiples and/or a combination of sources, e.g. laser and light emitting diodes.

[0083] Power for the machine **15** may be supplied from an internal battery (rechargeable and/or removable, if so desired), external battery, and/or line source. The provision of battery power frees the machine **15** from dependency upon electrical service. This feature makes it possible for the machine **15** to operate in multiple locations and while the patient is being transported between locations, e.g. from the holding area to the catheterization laboratory, from the catheterization laboratory to the holding area or hospital room, etc.

[0084] The applicator **30** can be sized and shaped to provide a suitable profile and area to enable irradiation of the intended tissue. For example, the applicator will be described herein for irradiation of the kidneys, understanding it is within the scope of this invention that the applicator may be sized and shaped for irradiation of other tissues within the body. Additionally, two or more applicators may be used to provide irradiation of each kidney and/or other target tissues as shown in FIG. **2**.

[0085] In this example, the applicator **30** is sized to irradiate at least both kidneys, taking into account the size and location of the kidneys, as well as the divergence of the electromagnetic energy within the tissue. For example, given the average kidney size of about 11 cm in height, by 6 cm in width, by 5 cm thick, at a depth of 7.5 cm, with a separation of 11 cm, a location asymmetry of 1 cm (the right kidney generally being lower than the left), and divergence of the electromagnetic radiation within the tissue of 15 degrees, an average applicator **30** would be about 20 cm by 9 cm. Applicators of varying sizes may be provided based on the patient's characteristics and/or the desired area of irradiation. The desired area of irradiation may be greater, equal to, or less than the size of the target tissue.

[0086] The applicator **30** may comprise a separate component within the energy path that is either reusable or disposable, or contain one or more components that are reusable or disposable. For example, a disposable membrane or component may be used for the portion of the applicator **30** that is in contact with the patient. This disposable membrane or component may also include the seal **60** and/or seal sensor **65**.

[0087] It may be desirable to secure the applicator to the patient. As shown in FIGS. **1** and **3**, all or at least some area of the applicator may have the ability to maintain attachment to the patient, e.g. have an adhesive, to minimize or eliminate movement of the applicator in relation to the patient, which may be called the seal **60**. The seal **60** may be the entire surface in contact with the patient or just a region, e.g. the outer edge as shown in FIG. **3**. Additional embodiments may comprise a strap, band, or wrap around the patient to secure the applicator **30**, or a separate component (not shown) that covers at least a portion of the applicator **30** and secures it to the patient, e.g. an adhesive strip. The securement of the applicator **30** may be designed to apply pressure to the patient's skin in the region of the applicator **30**. Securement of applicator **30** by the seal **60**, band, or other methods may serve as to direct the electromagnetic radiation energy to the patient and/or from eliminating any electromagnetic radiation of emanating into the surrounding area or environment.

[0088] The shape and size of the applicator **30** may also be provided such that it applies pressure to the patient in the region of the applicator **30**. The thickness of the applicator may be such that when the patient is laying on their back, e.g. on a catheterization laboratory table or surgical table, the applicator **30** applies pressure to the patient's skin.

[0089] It is desirable to apply pressure to the skin in the area of irradiation to decrease the amount of blood in the skin which decreases the absorption and increases transmission of the electromagnetic radiation to the kidney.

[0090] Additional methods and apparatuses to decrease the absorption and/or amount of blood and/or the blood vessel diameter in at least a portion of the area of electromagnetic irradiation is to decrease the temperature in at least a portion of the area. For example, this can be effected by cooling at least a portion of the applicator **30**, or by use of an independent cooling apparatus, prior to and/or concurrently with the delivery of electromagnetic radiation.

[0091] Additional methods to decrease the absorption and/or amount of blood and/or the blood vessel diameter in at least a portion of the area of electromagnetic irradiation are to apply an agent to at least a portion of the area. For example, this can be effected by applying a vasoconstrictive agent to at least a portion of the area prior to and/or concurrently with the delivery of electromagnetic radiation.

[0092] Additional methods to decrease the absorption and/or amount of blood and/or the blood vessel diameter in at least a portion of the area of electromagnetic irradiation are to apply an agent to at least a portion of the area. For example, this can be effected by administering a vasoconstrictive agent to the patient prior to and/or concurrently with the delivery of electromagnetic radiation.

[0093] Additional methods and apparatuses to decrease the absorption and/or amount of blood and/or the blood vessel diameter in at least a portion of the area of electromagnetic irradiation are to apply an energy source to at least a portion of the area. For example, this can be effected by applying a vasoconstrictive energy, e.g. electrical stimulation, to at least a portion of the area prior to and/or concurrently with the delivery of electromagnetic radiation.

[0094] Additional methods of providing pressure are to fill at least a portion of the applicator **30** or space between the applicator **30** and patient with a fluid. This fluid could be used, for example, thermal maintenance or cooling, to enhance transmission of the electromagnetic energy, etc. As shown in FIG. **3**, the region **70** not covered by the seal **60** may contain a transmission gel (not shown) to both enhance electromagnetic radiation transmission and apply pressure to the patient in the region of the applicator **30**. The transmission gel may be cooled and/or contain a vasoconstrictive agent.

[0095] The applicator **30** may contain a reflective component **80** or surface to direct electromagnetic radiation energy towards the patient, e.g. a reflective surface on the applicator **30** as shown in FIG. **1**.

[0096] The applicator **30** may be constructed of materials such that the applicator **30** is partially or wholly translucent or transparent under fluoroscopy, as to not completely inhibit visualization in the catheterization laboratory.

[0097] The applicator **30** and a portion of the interconnect **40** may be constructed of materials that enable use within a magnetic field, e.g. an MRI machine.

[0098] The interconnect **40** couples the machine **15** to the applicator **30**. The interconnect **40** may be a separate component or it may be part of the machine **15** and/or part of the applicator **30**. The interconnect **40** enables the transmission of electromagnetic radiation from the machine **15** to the applicator **30**. In addition, the interconnect **40** may also include electrical and optical components, as will be described herein. The interconnect **40** may be sized to enable the applicator **30** to remain within a sterile field while the machine **15** is outside the sterile field, when used in sterile settings.

[0099] A controller **50** may have one or more functions. These functions may include but are not limited to, power on/off control, set and/or track the time of electromagnetic radiation delivery, initiate and/or cease electromagnetic radiation delivery, change the energy of the source **20** based on the applicator connected to it, control operation of multiple sources **20** (e.g. laser and light emitting diode sources), monitor and/or control thermal and/or cooling components and/or modify source **20** output parameters and/or energy delivery based on feedback from one or more sensors (e.g. thermal and/or optical sensors), and control continuous and/or pulsed mode operation. A controller **50** or other component may also recognize the status of the system **10** connections (e.g. the machine **15** to the interconnect **40** and/or the interconnect **40** to the applicator **30**) and only allow electromagnetic energy delivery when properly connected. A controller **50** or other component may also recognize the type and/or status of the applicator **30** and only allow electromagnetic energy delivery when the proper applicator **30** is connected.

[0100] Total power output may be adjusted to provide for similar power density at the target tissue. Provided different sized applicators, the source could deliver a lower amount of power for a smaller applicator for the same target tissue. This could be manually changed at a controller **50** or preprogrammed from recognition of the applicator size and appropriate adjustment of the output power by a controller **50**. Power level may also be adjusted based on the patient's characteristics, e.g. size, weight, body mass index, body surface area, etc.

[0101] Thermal sensing at or near the patient interface may be desirable. Additionally, thermal control of and/or near the applicator **30** and/or patient interface may also be desirable. The thermal control may, for example, be a sensor to monitor the temperature at and/or near the applicator **30**, and/or whereby a controller **50** adjusts the power output of the source **20**, operates an active cooling system (FIG. **4**), changes output mode (to/from continuous to/from pulsed to/from cycled off and on in either mode), ceases power output.

[0102] A cooling system **90** as shown in FIG. **4**, may be incorporated into the system **10** or be a separate system. The cooling system **90** may be provided to reduce or eliminate thermal increases of at least a portion of the patient's tissue and/or to maintain a desirable thermal range. The cooling system **90** may also be used to decrease the amount of blood and/or the blood vessel diameter in at least a portion of the region of electromagnetic radiation.

[0103] Thermal control may be passive, for example, a fluid filled applicator **30** being filled with and/or incorporating a cold liquid, solid, or gel. The decreased temperature may be from cold storage of the component, through a chemical reaction, or other mechanism. The thermal control may be active, e.g. circulating cold fluid through at least a portion of the applicator **30** or the region of the patient interface. A sensor may be used as feedback to control the cooling system to maintain certain parameters, e.g. a specific temperature or a temperature range.

[0104] It is desirable to eliminate the need to use safety glasses when using certain wavelengths and/or energy levels of electromagnetic radiation energy. The system may enable the detection of specific wavelengths, and/or multiple wavelengths, and/or a range and/or ranges of wavelengths and/or the detection of the intensity of the electromagnetic radiation. Upon detection, at least one additional operation may be conducted by the system **10**, e.g. cease energy delivery and/or provide a warning indicator (light, tone).

[0105] An example of a detection system is partially shown in FIG. **3**, where an optical seal sensor **65** is placed within the seal **60** of the applicator **30**. The seal sensor **65** is connected the machine **15** via the interconnect **40** or a separate interconnect (not shown). Upon sensing the delivered wavelength(s) with or through the seal sensor **65**, in the case of the seal **60** not containing all the electromagnetic radiation, the system **10** conducts an additional operation.

[0106] Another example of a detection system is an electromagnetic radiation sensor **66** shown in FIG. **1**, which detects the delivered wavelength(s) should the system **10** irradiate an undesirable area, e.g. towards persons other than the patient, into the catheterization laboratory, surgical suite, environment, etc. In this case, if the minimum threshold energy of the delivered electromagnetic radiation wavelength(s) is exceeded, the system **10** conducts an additional operation. Minimum threshold energy level may be determine by sensing ambient energy levels prior to the delivery of electromagnetic radiation, and having the threshold level set at a value greater than ambient, e.g. 10% above ambient.

[0107] It is within the scope of the invention that placement and type of sensor or sensors may be varied as well as the operation or operations conducted by the sensor, and/or controller **50**, and/or system **10**.

[0108] The electromagnetic radiation may also be delivered either in continuous mode, pulsed mode, or both. In the case of a single source **20**, the output, for example, may alternate between continuous mode and pulsed mode, or may begin as continuous mode and in the case of thermal increases, switch to pulsed mode. In the case of multiple sources **20**, sources **20** may operate in continuous mode and/or pulsed mode and switch between the two. Various combinations of continuous mode and pulsed mode operation are within the scope of the present invention.

[0109] The machine **15** provides efficacious electromagnetic radiation energy preferably at a wavelength within the visible and/or infrared range, about 380 nm to 1560 nm, and more preferably within the red and/or near infrared range, about 635 nm to 980 nm. Most preferably the wavelength is in the near infrared range at about 808 nm.

[0110] Multiple sources **20** may generate electromagnetic radiation energy at the same or different wavelengths and the same or different energy levels, e.g. light emitting diode(s) operating at 635 nm and a laser operating at 808 nm with similar of different energy levels. Irradiation of the tissue from each source **20** may occur at separate time points and/or at the same time and/or combinations thereof. Operating modes for the delivery of electromagnetic radiation energy may be continuous wave, pulsed wave, and/or a combination within each source and between sources.

[0111] It is preferable that the efficacious power density at the target tissue be at least 0.01 mW/cm^2. More preferably the power density at the target tissue is 1 mW/cm^2 to 300 mW/cm^2. Most preferably the power density at the target tissue is 1 mW/cm^2 to 50 mW/cm^2 in continuous mode and in pulsed mode the peak power density is 5 mW/cm^2 to 250 mW/cm^2.

[0112] The absorption properties of electromagnetic radiation in living tissue, organs, blood, etc are affected by the wavelength. The use of electromagnetic radiation with wavelengths of comparatively higher levels of absorption in human tissue, e.g. 635 nm versus 808 nm, it may be advantageous to deliver pulsed wave mode electromagnetic radiation as compared to continuous wave mode to decrease the thermal load and/or enable the use of higher power densities at the skin surface.

[0113] The use of pulsed mode electromagnetic radiation at higher power densities at the skin surface enables higher peak power densities to be achieved at the kidney tissue and/or potentially expands the range of useful wavelengths able to deliver efficacious energy to the kidney tissue.

[0114] Using the example of an applicator **30** sized 20 cm by 9 cm, estimating 10% of the energy at the skin surface delivered to the opposite side of the kidneys from the applicator (a depth of about 10 cm), a power density of 10 mW/cm^2 at the opposite side of the kidney from the applicator, and 15 degrees divergence of the electromagnetic radiation within the tissue, provides the parameters listed in Table 1.

TABLE 1

	Skin surface	Kidney depth
Area of irradiation	180 cm^2	390 cm^2
Power density	217 mW/cm^2	10 mW/cm^2
Total power	39,000 mW	3,900 mW

[0115] Based on these assumptions, to provide a minimum power density of 10 mW/cm^2 to the, entire area of both kidneys with a single applicator **30**, the source **20** would need to provide 39 W of power output from the applicator **20**.

[0116] In the example above, the power density was measured at the opposite side of the kidney from the applicator. However, the efficacious power density range applies to power densities delivered to the surface of the kidney and/or within the kidney and/or at the opposite side of the kidney from the applicator.

[0117] The efficacious wavelength and power density ranges are suitable to prevent, decrease, or eliminate tissue injury or damage resulting from, for example, ischemia and/or an ischemic event and/or external and/or intrinsic toxicity. With respect to the example provided for the prevention, reduction, or elimination of acute kidney injury and/or kidney failure; and/or before, during, or after the acute kidney injury and/or kidney failure has begun; and/or before, during, or after a new kidney injury and/or insult has occurred, these efficacious wavelength and power density ranges are suitable to prevent, decrease, or eliminate tissue injury or damage resulting from pre-renal, renal or intrinsic, and post-renal causes.

[0118] An alternative embodiment is to introduce electromagnetic radiation to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, and administering a pharmacologic agent (e.g. hydration, volume expansion, N-acetylcysteine, sodium bicarbonate, ascorbic acid) prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0119] An alternative embodiment is to introduce electromagnetic radiation to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after an interventional procedure, and administering a pharmacologic agent (e.g. hydration, volume expansion, N-acetylcysteine, sodium bicarbonate, ascorbic acid) prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0120] An alternative embodiment is to provide a combination system **100** with the electromagnetic radiation energy source near and/or adjacent to, and/or being part of the applicator. This combination source/applicator **130** as shown in FIG. **5**, is for example, a light emitting diode array as part of the applicator. Combination system **100** may contain and/or a combination controller **150**, source/power supply **117** (internal or external), source/power interconnect **140**. All features described as part of the present invention are applicable to a combination system **100**.

[0121] An alternative embodiment is to provide a multiple source system **200** with two sources, e.g. a laser and a light emitting diode array as shown in FIG. **6**. For example, the multiple source system **200** may comprise an applicator containing or near or adjacent to at least one electromagnetic radiation energy source and/or at least one source not at, near, or adjacent the applicator. This multiple source/applicator

230 is for example, a light emitting diode array **226** as part of the applicator and a laser source **220** with an output window **225** located at, near, or adjacent the patient. The multiple source/applicator **230** would provide for irradiation of the patient by both sources, from the light emitting diode array **226** and from the laser source through the output window **225**. Multiple source system **200** may contain and/or at least one multiple source controller **250**, multiple source power supply **217**, power/electromagnetic radiation interconnect **240**. All features described as part of the present invention are applicable to a multiple source system **200**.

[0122] Electromagnetic radiation energy may be used with other energy delivery sources at separate time points and/or at the same time and/or combinations thereof. Examples of such sources are, but not limited to, acoustic energy (including ultrasound) and magnetic energy, and electrical energy. Application of multiple energies may provide an enhanced effect compared to electromagnetic energy alone.

[0123] Clinical examples using certain embodiments of the apparatuses and methods are provided. These examples demonstrate some of the wide range of possible combinations of certain embodiments of the present invention. The present invention, is, of course, not limited to these examples and other uses of this invention will be apparent to those skilled in the art.

EXAMPLE 1

[0124] Angiography: A patient requires an angiogram. Prior to the angiogram, the patient is determined to be at high risk for kidney injury due to the use of contrast media. It is determined to use system **10** to prevent, reduce, or eliminate kidney injury.

[0125] Transmission gel is cooled and applied to the region **70** of the applicator **30**. Applicator **30** is secured to patient's back using seal **60**, in the region of the kidneys (generally located between T12 to L3). The applicator **30** is connected to interconnect **40** and machine **15**. The patient lies on their back on the catheterization laboratory table and by design of the applicator **30**, pressure is applied to the patient's skin in the area covered the applicator **30**. Continuous mode transmission of electromagnetic energy from laser source **20** at 808 nm and a power density of 2 mW/cm^2 at the far side of the kidneys is initiated 15 minutes prior to first contrast injection and is delivered for a duration of 10 minutes.

EXAMPLE 2

[0126] Angiography 2: A patient requires an angiogram. Prior to the angiogram, the patient is determined to be at high risk for kidney injury due to the use of contrast media. It is determined to use system **10** to prevent, reduce, or eliminate kidney injury.

[0127] The patient receives and angiogram. After the angiogram, a vasoconstrictive agent is applied to the patient contact surface of the source/applicator **230**. Transmission gel is cooled and applied to the region **70** of the applicator **30**. Applicator **30** is secured to patient's back using seal **60**, in the region of the kidneys (generally located between T12 to L3) and by design of the applicator **30**, pressure is applied to the patient's skin in the area covered the applicator **30**. The applicator **30** is connected to interconnect **40** and machine **15**. Pulsed mode transmission of electromagnetic energy from laser source **20** at 635 nm and a power density of 10 mW/cm^2 at the surface of the kidneys is delivered for a duration of 2 minutes. Additional irradiations may occur at various intervals. These include but are not limited to once only or one or more times per day for one or more days or one or more times per day with a day or days without irradiation interspersed between irradiation days, e.g. skip days.

EXAMPLE 3

[0128] Percutaneous transluminal coronary angioplasty: A patient requires percutaneous transluminal coronary angioplasty (PTCA). Prior to the PTCA, the patient is determined to be at high risk for kidney injury due to the use of contrast media. It is determined to use system **10** to prevent, reduce, or eliminate kidney injury.

[0129] Transmission gel is applied to the region **70** of the applicator **30**. Applicator **30** is secured to patient's back using seal **60**, in the region of the kidneys. The applicator **30** is connected to interconnect **40** and machine **15** and machine **15** is plugged into wall power. The patient lies on their back and by design of the applicator **30**, pressure is applied to the patient's skin in the area covered the applicator **30**. Continuous mode transmission of electromagnetic energy from laser source **20** at 808 nm and a power density of 10 mW/cm^2 at the surface of the kidneys is delivered for 2 minutes duration, initiated 30 minutes prior to first contrast injection. Seal sensor **65** continuously monitors for 808 nm electromagnetic radiation, does not detect any, and continues delivery of energy. Continuous wave electromagnetic radiation energy is delivered again at 6 hours post procedure and twice per day with a 6 hour separation between irradiations for one or more days following the procedure. System **10** operates on battery power while patient is moved between areas, where the machine **15** may be plugged back into wall power. The controller **50**, if operating in continuous mode, may switch to pulsed mode and deliver pulsed mode electromagnetic radiation energy, e.g. if there is an increase in temperature. Based on the patient's status, delivery of electromagnetic radiation energy may be cycled on and off by the controller **50**.

EXAMPLE 4

[0130] Coronary artery bypass graft surgery: A patient requires a coronary artery bypass graft surgery. It is determined to use combination system **200**, incorporating cooling system **90**, to prevent, reduce, or eliminate kidney injury.

[0131] Transmission gel is applied to the region **70** of the multiple source/applicator **230**. Multiple source/applicator **230** is secured to patient's back using seal **60**, in the region of the kidneys (T12 to L3). The multiple source/applicator **230** is connected to the power/electromagnetic radiation interconnect **240** and multiple source power supply **217**. Disposable membrane of multiple source/applicator **230** is fluid filled to exert pressure on the patient's skin. A transmission gel containing a vasoconstrictive agent is applied to the patient contact surface of the source/applicator **230**. Continuous mode transmission of electromagnetic radiation energy from light emitting diode array **226** at 635 nm and 25 mW/cm^2 and pulsed mode electromagnetic radiation energy is delivered through output window **225** at 808 nm and a power density of 25 mW/cm^2 at the kidneys. Two minutes of electromagnetic radiation is delivered 24 hours prior to the procedure, during which electromagnetic radiation sensor **66** continuously monitors for electromagnetic radiation in the 600 nm to 900 nm range, does not detect any amount above the threshold level, and allows delivery of energy. System **10** operates on battery power in case the patient needs to be moved until the multiple source power supply **217** is plugged back into wall power. The multiple source controller **250** may switch off the 808 nm source and continue delivery of the 635 nm electromagnetic radiation energy, now switched to pulsed mode. During irradiation, the cooling system **90** is cycled by the multiple source controller **250** to maintain a preset temperature and reduce blood flow in the area. Based on the patient's status, electromagnetic radiation energy may be delivered from either or both sources at a variety of power levels and modes of operation, or discontinued. Similarly, an additional 2 minutes of electromagnetic radiation is delivered to the patient during the procedure and every 24 hours post procedure for an additional three days.

[0132] Another preferred embodiment of the present invention is a method for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after the acute kidney injury and/or kidney failure has begun; and/or before, during, or after a new kidney injury and/or insult has occurred.

[0133] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after surgery.

[0134] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after the introduction of contrast media to the patient.

[0135] A method is provided for preventing, reducing, or eliminating contrast-induced nephropathy by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after the introduction of contrast media to the patient.

[0136] A method is provided for preventing, reducing, or eliminating contrast-induced nephropathy by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after angiography.

[0137] A method is provided for preventing, reducing, or eliminating contrast-induced nephropathy by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and/or before, during, or after contrast-enhanced imaging.

[0138] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. Prior to the introduction of contrast media to the patient, the patient is identified as being at risk of experiencing acute kidney injury and/or kidney failure. Electromagnetic radiation energy at an efficacious wavelength and power density is delivered to at least a portion of the patient's kidney or kidneys before and/or during and/or after the introduction of contrast media to the patient.

[0139] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. Prior to a diagnostic and/or interventional procedure, the patient is identified as being at risk of experiencing acute kidney injury and/or kidney failure. Electromagnetic radiation energy at an efficacious wavelength and power density is delivered to at least a portion of the patient's kidney or kidneys before and/or during and/or after the diagnostic and/or interventional procedure.

[0140] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. Prior to surgery, the patient is identified as being at risk of experiencing acute kidney injury and/or kidney failure. Electromagnetic radiation energy at an efficacious wavelength and power density is delivered to at least a portion of the patient's kidney or kidneys before and/or during and/or after the surgery.

[0141] A method is provided for preventing, reducing, or eliminating contrast-induced nephropathy by the application of electromagnetic radiation energy. Prior to the introduction of contrast media to the patient, the patient is identified as being at risk of experiencing contrast-induced nephropathy. Electromagnetic radiation energy at an efficacious wavelength and power density is delivered to at least a portion of the patient's kidney or kidneys before and/or during and/or after the introduction of contrast media to the patient.

[0142] A method is provided for changing or maintaining the temperature of at least a portion of the patient's tissue prior to and/or during and/or after irradiating at least a portion of the patient's kidney with electromagnetic energy.

[0143] A method is provided for changing the pressure on at least a portion of the patient's skin and/or tissue prior to and/or during and/or after irradiating at least a portion of the patient's kidney with electromagnetic energy.

[0144] A method is provided for decreasing the absorption and/or amount of blood and/or the blood vessel diameter in at least a portion of the area of electromagnetic irradiation prior to and/or during and/or after irradiating at least a portion of the patient's kidney with electromagnetic energy.

[0145] A method is provided for sensing at least one electromagnetic energy wavelength and performing an operation if that at least one wavelength is detected.

[0146] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure by the application of electromagnetic radiation energy. At least a portion of one kidney is irradiated with electromagnetic radiation energy at an efficacious wavelength and power density and at least one additional energy is delivered to at least a portion of one kidney and/or before, during, or after the acute kidney injury and/or kidney failure has begun; and/or before, during, or after a new kidney injury and/or insult has occurred.

[0147] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of and/or after the kidney injury, and administering a pharmacologic agent prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0148] A method is provided for preventing, reducing, or eliminating acute kidney injury and/or kidney failure. The method comprises introducing electromagnetic radiation of at least one efficacious wavelength and energy to at least a portion of kidney tissue, prior to and/or at least during a portion of the time of an interventional procedure, and administering a pharmacologic agent prior to and/or at least during a portion of the time of and/or after electromagnetic radiation, to prevent, reduce, or eliminate injury to the kidney tissue.

[0149] The present invention is not to be considered to be limited to the foregoing examples and description, but is of the full scope of the appended claims.

1. A method of preventing or treating kidney injury comprising subjecting kidney tissue to electromagnetic radiation in the red-near infrared range for a period of time sufficient to prevent or reduce injury to the kidney.

2. The method of claim **1** wherein the electromagnetic energy is laser energy.

3. The method of claim **2** wherein the energy has a wavelength of about 635 nm to about 1560 nm.

4. The method of claim **1** wherein the electromagnetic energy is light emitting diode energy.

5. The method of claim **4** wherein the energy has a wavelength of about 635 nm to about 1560 nm.

6. The method of claim **1** wherein the electromagnetic radiation has a power density of at least 0.01 mW/cm^2 at the kidney tissue.

7. The method of claim **1** wherein at least a portion of the electromagnetic radiation is delivered prior to the injury to the kidney.

8. The method of claim **7** wherein the injury to the kidney is due at least in part to a contrast agent.

9. The method of claim **1** wherein at feast a portion of the electromagnetic radiation is delivered during the injury to the kidney.

10. The method of claim **9** wherein the injury to the kidney is due at least in part to a contrast agent.

11. The method of claim **1** wherein at least a portion of the electromagnetic radiation is delivered after the injury to the kidney.

12. The method of claim **11** wherein the injury to the kidney is due at least in part to a contrast agent.

13. The method of claim **1** wherein said kidney injury is induced by a pre-renal cause.

14. The method of claim **1** wherein said kidney injury is induced by a renal cause.

15. The method of claim **1** wherein said kidney injury is induced by a post-renal cause.

16. The method of claim **1** wherein a region of the patient's skin is cooled.

17. The method of claim **1** wherein the absorption of electromagnetic radiation in at least a portion of the area exposed to the electromagnetic radiation is decreased.

18. The method of claim **1** wherein sensing for electromagnetic radiation is conducted concurrently with the delivery of the electromagnetic radiation.

19. The method of claim **1** wherein a pharmacologic agent is administered to the patient to enhance reduction or prevention of injury to the kidney.

20. The method of claim **19** wherein the pharmacologic agent is selected from the group of angiotensin II, fenoldopam, dopamine, calcium-channel blockers, endothelin antagonists, adenosine, N-acetylcysteine, sodium bicarbonate, and ascorbic acid.

21. The method of claim **1** wherein multiple wavelengths of electromagnetic radiation are applied to at least a portion of kidney tissue.

22. The method of claim **1** wherein a non-electromagnetic energy is applied concurrently with the electromagnetic radiation to at least a portion of kidney tissue.

23. Apparatus for preventing or treating kidney injury comprising a source of electromagnetic energy in the red-near infrared range, an applicator adapted to emit and transmit said electromagnetic energy to kidney tissue.

24. Apparatus for preventing or treating kidney injury comprising a source of electromagnetic energy in the red-near infrared range, a conduit for transmitting said energy and an applicator adapted to emit and transmit said electromagnetic energy to kidney tissue.

25. The apparatus of claim **23**, wherein the energy source is a laser.

26. The apparatus of claim **23**, wherein the energy has a wavelength of about 635 nm to about 1560 nm.

27. The apparatus of claim **23** wherein the energy source is a light emitting diode.

28. The apparatus of claim **23**, wherein the energy has a power density of at least 0.01 mW/cm^2 at the kidney tissue.

29. The apparatus of claim **23**, wherein the energy is delivered in pulsed mode at a peak power density of at least 0.01 mW/cm^2 at the kidney tissue.

30. The apparatus of claim **23**, further comprising an element to measure the temperature near the skin.

31. The apparatus of claim **23**, further comprising an element in contact with the skin. The element adapted to reduce thermal changes near the skin.

32. The apparatus of claim **23**, further comprising an element adapted to reduce the blood flow near the skin.

33. The apparatus of claim **23**, further comprising an element for sensing electromagnetic radiation.

34. The apparatus of claim **23**, further comprising an element for sealing the applicator to the patient.

35. The apparatus of claim **23**, wherein the applicator is secured to the patient.

36. The apparatus of claim **23**, further comprising a controller.

37. The apparatus of claim **23**, further comprising two or more applicators adapted to emit and transmit said electromagnetic energy to kidney tissue.

38. The apparatus of claim **23**, further comprising at least one applicator capable of transmitting multiple wavelengths of said electromagnetic energy to kidney tissue.

39. The apparatus of claim **23**, further comprising at least one acoustic energy source of at least one efficacious energy.

40. The apparatus of claim **23**, further comprising at least one magnetic field source of at least one efficacious field strength.

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