stimulate a nerve or a fascicle varies non-linearly with the distance, varies at injection of fluids, tissue density and/or by mechanical pressure of the needle tip on a fascia.

[009] The variables of current charge (intensity) and tissue impedance to the electric stimulus have made it difficult to standardize a technique to enable precise needle to nerve distance and relationship respective to the layers of a specific fascicle, nerve and/or plexus. Nonetheless, an EMR at a very low current has been found to be highly specific of intra-neural location of the needle tip.

[0010] Injection pressure monitoring (IPM) is highly sensitive to detect a peak pressure as soon as the needle tip encounters a dense connective tissue. However, IPM is not specific of the nature of the dense connective tissue. A low-pressure range is specific of a low-density tissue loose connective tissue such as fat, interstitium, or muscle. A high-pressure range is specific of a dense connective tissue (fascia, tendon, nerve…) but a pressure signature is not highly specific of the tissue type. For instance, a tendon and a nerve have similar aspect on an ultrasound image. Indenting the surface layer of the tendon and the nerve may produce similar high peak pressure. Similarly, IPM cannot differentiate paraneural from extra-neural interstitium.

Tissue density	Dense	Intermediate	Loose
Evoked motor response to NS	Perineurium Outer epineurium	Inner epineurium	paraneurium
no motor response	Tendon Muscle fascia	Intermuscular fascial plane	Subcutaneous fat Intermuscular, perivascular interstitium

Summary of the Invention

[0010a] According to a first aspect of the present invention, there is provided a system for providing a peripheral nerve block to a patient, comprising:

a needle having a sharpened tip;

a fluid pump providing a flow of fluid to the needle,

a controller for controlling the fluid pump to control the flow of fluid to the needle;

a sensor for detecting the fluid pressure in the needle; and

a conductive element for providing an electric nerve stimulation at the tip of the needle;

wherein the controller is configured to provide varying electrical stimulation in response to the sensor detecting a fluid pressure above a first threshold, and

wherein the controller is configured to provide a constant stimulation at a baseline current when the detected fluid pressure is below the first threshold.

[0010b] There is also provided an apparatus for injecting medicinal fluid, comprising:

an injection system for controlling a flow of fluid from a fluid reservoir to a needle, wherein the needle is configured for subcutaneous insertion into a mammalian subject;

a sensor for detecting a characteristic indicative of the fluid pressure in the needle, wherein the sensor is configured to continuously detect the characteristic as the needle is inserted into the subject; and

an electric nerve stimulation element for providing an electric nerve stimulation at or adjacent to a tip of the needle;

wherein the electric nerve stimulation element varies the intensity of the electric nerve stimulation to a patient after the sensor detects a characteristic of the fluid pressure indicative of the fluid pressure exceeding a first threshold.

[0010c] There is also provided a system for injection fluid into a patient, comprising:

a needle having a sharpened tip;

a fluid pump providing a flow of fluid to the needle,

a controller for controlling the fluid pump to control the flow of fluid to the needle;

a sensor for detecting the fluid pressure in the needle; and

a conductive element for providing an electric nerve stimulation at the tip of the needle;

wherein the controller is configured to control the fluid pump to provide a dose of fluid in response to a signal from the sensor indicative of a pressure exceeding a threshold and the absence of a signal indicative of an electric motor response in response to electric nerve stimulation when the electric nerve stimulation exceeds a threshold intensity.

[0011] Ultrasonography allows simultaneous visualization of the target nerve, needle, local anesthetic solution and surrounding anatomical structures. Nevertheless, ultrasonography as a sole method of monitoring may not reliably prevent neurologic injury. Nerve stimulation has low sensitivity to differentiate relative needle tip position to the nerve layers but is highly specific of neural tissue nearness. Injection pressure

CLAIMS

What is claimed is:

1. A system for providing a peripheral nerve block to a patient, comprising:

a needle having a sharpened tip;

a fluid pump providing a flow of fluid to the needle,

a controller for controlling the fluid pump to control the flow of fluid to the needle;

a sensor for detecting the fluid pressure in the needle; and

a conductive element for providing an electric nerve stimulation at the tip of the needle;

wherein the controller is configured to provide varying electrical stimulation in response to the sensor detecting a fluid pressure above a first threshold, and

wherein the controller is configured to provide a constant stimulation at a baseline current when the detected fluid pressure is below the first threshold.

2. The system of claim 1 wherein the conductive element is operable to provide an electrical charge of intensity of between 0.10 mA up to 6.0 mA , short duration of 0.05 to 1 Ms and frequency 1, or 2 to 4 Hertz, and a maximum voltage of 100 volts, and optionally the electrical stimulation element is operable to provide stimuli for 1 - 10 seconds.

3. The system of claim 1 or claim 2 wherein the conductive element is operable to provide a constant, incremental or decremental current charge.

4. The system of any one of claims 1-3 wherein the controller is configured to provide continuously varying electrical stimulation according to a charge profile consisting of a set of pre-defined pre-set charge values.

5. The system of claim 4 wherein the charge profile provides a series of electrical impulses which start with a first electric impulse and increase incrementally in

stepwise fashion to a maximum value and then re-set to the minimum value thereby generating a series of impulses that continuously vary in stepwise fashion.

6. The system of claim 1 wherein the controller is configured to store a plurality of charge profiles that include data regarding various characteristics of the electrical stimulation to be provided; wherein the charge profile includes a maximum charge current and a minimum charge current.

7. The system of claim 6 wherein the charge profile includes a plurality of charge values between the maximum and the minimum.

8. The system of claim 7 wherein the charge profile includes the baseline current and the first pressure threshold.

9. The system of any of claims 1-8 wherein the controller is configured to discontinue the flow of fluid to the needle in response to the sensor detecting a fluid pressure above a second threshold and indication of an evoked muscle response from the electric nerve stimulation.

10. The system of claim 9 wherein the second threshold is different from the first threshold.

11. The system of claim 9 wherein the second threshold is the same as the first threshold.

12. The system of any of claims 1-11 comprising a remote actuator for providing signal to control operation of the fluid pump or the electric nerve stimulation.

13. The system of any of claims 1-12 comprising an output element configured to provide a human perceptible signal in response to a determination that the tip of the needle is within a nerve.

14. The system of any of claims 1-13 comprising an input element configured to allow the operator to indicate whether an evoke motor response was observed in response to the electric nerve stimulation.

15. The system of any of claims 1-14 comprising a sensor for detecting an evoked motor response in response to the electric nerve stimulation.

16. The system of claim 15 wherein the sensor for detecting an evoke motor response comprises an accelerometer or electromyograph sensor.

17. The system of any of claims 1-16 wherein the controller is configured to control the fluid pump to provide a dose of fluid in response to a signal from the sensor indicative of a pressure exceeding a threshold and the absence of a signal indicative of an electric motor response in response to electric nerve stimulation exceeding a threshold intensity.