[0006] On the other hand, the thoracic and abdominal regions of the body are far more mobile than the skull is, due to general movement of the body and respiration. This substantially increased degree of movement can cause the transducer arrays not to adhere to thoracic and abdominal regions with the degree of intimacy of contact and/or duration of contact that may be desired. Higher levels of perspiration from these areas also make it more challenging to achieve good long-term, intimate adhesion of the transducer arrays to the skin.

SUMMARY OF THE INVENTION

[0007] One aspect of the invention is directed to a first electrode apparatus configured for affixation to a patient's skin. The first apparatus comprises a flex circuit having a trunk region that extends in a longitudinal direction and a plurality of branches that extend laterally from the trunk region, each of the b ranches having a free distal end and a proximal end that is connected to the trunk region, with ~~a~~ the plurality of branches extending on at least one lateral side of the trunk region, the flex circuit having an inner skin-facing side and an outer side. The first apparatus also comprises a plurality of electrode elements disposed on the inner side of the flex circuit along the branches of the flex circuit, each of the electrode elements having a conductive plate that is connected to the flex circuit in an electrically conducting manner, and a dielectric layer positioned to face the skin of the patient. The first apparatus also comprises a top, covering layer disposed on the outer side of the flex circuit, the covering layer being sized to cover the branches of the flex circuit and to overlap spaces between the branches, the covering layer having adhesive on a skin-facing side thereof by means of which the covering layer can be adhered to the patient's skin through the spaces between the branches. The covering layer is slotted to define a plurality of fingers overlying the branches of the flex circuit so that the fingers of the covering layer can move independently of each other as branches of the flex circuit flex independently of each other.

[0008] Some embodiments of the first apparatus further comprise a plurality of conductive hydrogel discs, wherein each of the conductive hydrogel discs is attached to a skin-facing side of a respective electrode element. Some of these embodiments further comprise a plurality of gel barriers, wherein each of the gel barriers surrounds a respective one of the hydrogel discs.

[0009] Some embodiments of the first apparatus further comprise a foam layer disposed on the inner side of the flex circuit, wherein the foam layer is configured to cover at least a portion of the trunk region of the flex circuit and at least a portion of the branches of

the flex circuit, and leave the electrode elements uncovered. Some of these embodiments further comprise a skin-level adhesive layer disposed on a skin-facing side of the foam layer. In some of these embodiments, the skin-level adhesive layer has a configuration that follows the configuration of the flex circuit, with branches and trunk portions of the skin-level adhesive layer being wider than corresponding portions of the flex circuit so as to overlap spaces between the branches of the flex circuit.

[0010] In some embodiments of the first apparatus, more electrode elements are attached to branches of the flex circuit that are closer to the longitudinal center of the trunk than are attached to branches of the flex circuit that are ~~farther from~~ closer to the longitudinal ends of the trunk. In some embodiments of the first apparatus, the trunk shifts back and forth in the lateral direction as it extends in the longitudinal direction. In some embodiments of the first apparatus, the trunk extends in the longitudinal direction in a straight manner.

[0011] Some embodiments of the first apparatus further comprise a skin-level adhesive layer disposed on the inner side of the flex circuit. In some of these embodiments, the skin-level adhesive layer has a configuration that follows the flex circuit, with branches and trunk portions of the skin-level adhesive layer being wider than corresponding portions of the flex circuit so as to overlap spaces between the branches of the flex circuit.

[0012] Some embodiments of the first apparatus further comprise a skin-level adhesive layer disposed on the inner side of the flex circuit, wherein the skin-level adhesive layer is attached directly to the inner side of the flex circuit.

[0013] In some embodiments of the first apparatus, the flex circuit has a respective plurality of the branches extending on each lateral side of the trunk region. In some embodiments of the first apparatus, the flex circuit is configured so that no more than three paths emanate from any intersection on the flex circuit. In some embodiments of the first apparatus, the flex circuit is configured so that four paths emanate from only a single intersection on the flex circuit, and no more than three paths emanate from any other intersection on the flex circuit. In some embodiments of the first apparatus, the flex circuit is configured so that all segments of the flex circuit are straight.

[0014] Some embodiments of the first apparatus further comprise an electrical cable that terminates on the flex circuit, and segments of the flex circuit near the distal end of each

branch are thinner than at least some of the segments of the flex circuit that are adjacent to the electrical cable.

[0015] There is also disclosed an electrode apparatus configured for affixation to a patient's skin. The second apparatus comprises a flex circuit having a trunk region that extends in a longitudinal direction and a plurality of branches that extend laterally from the trunk region, each of the branches having a free distal end and a proximal end that is connected to the trunk region, with ~~a~~ the plurality of branches extending on at least one lateral side of the trunk region, the flex circuit having an inner skin-facing side and an outer side. The second apparatus also comprises a plurality of electrode elements disposed on the inner side of the flex circuit along the branches of the flex circuit, each of the electrode elements having a conductive plate that is connected to the flex circuit in an electrically conducting manner, and a dielectric layer positioned to face the skin of the patient. The second apparatus also comprises a foam layer disposed on the inner side of the flex circuit, wherein the foam layer is configured to cover at least a portion of the trunk region of the flex circuit and at least a portion of the branches of the flex circuit, and leave the electrode elements uncovered. The second apparatus also comprises a skin-level adhesive layer disposed on a skin-facing side of the foam layer. The second apparatus also comprises a top, covering layer disposed on the outer side of the flex circuit, the covering layer being sized to cover the branches of the flex circuit and to overlap spaces between the branches, the covering layer having adhesive on a skin-facing side thereof by means of which the covering layer can be adhered to the patient's skin through the spaces between the branches.

[0016] Some embodiments of the second apparatus further comprise a plurality of conductive hydrogel discs, wherein each of the conductive hydrogel discs is attached to a skin-facing side of a respective electrode element. Some of these embodiments further comprise a plurality of gel barriers, wherein each of the gel barriers surrounds a respective one of the hydrogel discs.

[0017] In some embodiments of the second apparatus, more electrode elements are attached to branches of the flex circuit that are closer to the longitudinal center of the trunk than are attached to branches of the flex circuit that are ~~farther from~~ closer to the longitudinal ends of the trunk.

[0018] In some embodiments of the second apparatus, the trunk shifts back and forth in the lateral direction as it extends in the longitudinal direction.

[0019] In some embodiments of the second apparatus, the trunk extends in the longitudinal direction in a straight manner.

[0020] In some embodiments of the second apparatus, the covering layer is slotted to define a plurality of fingers overlying the branches of the flex circuit so that the fingers of the covering layer can move independently of each other as branches of the flex circuit flex independently of each other. In some embodiments of the second apparatus, the flex circuit has a respective plurality of the branches extending on each lateral side of the trunk region. In some embodiments of the second apparatus, the foam layer is configured to cover the entire surface of the flex circuit, except for regions where the electrode elements are positioned.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 is an exploded view of one embodiment of a transducer array that has a first layout of electrode elements.

[0022] FIG. 2 is a plan view of the flex circuit used in the transducer array illustrated in FIG. 1.

[0023] FIG. 3 is a plan view of the electrode elements used in the transducer array illustrated in FIG. 1.

[0024] FIG. 4 is a plan view of stiffeners used in the transducer array illustrated in FIG. 1.

[0025] FIG. 5 is a plan view of conductive hydrogel discs used in the transducer array illustrated in FIG. 1.

[0026] FIG. 6A is a plan view of hydrogel barriers used in the transducer array illustrated in FIG. 1.

[0027] FIG. 6B is a view of the hydrogel discs and hydrogel barriers as “seen” by the patient’s skin.

[0028] FIG. 7A is a plan view of a skin-level adhesive layer used in the transducer array illustrated in FIG. 1.

WHAT IS CLAIMED IS:

1. An electrode apparatus configured for affixation to a patient's skin, comprising:

a flex circuit having a trunk region that extends in a longitudinal direction and a plurality of branches that extend laterally from the trunk region, each of the branches having a free distal end and a proximal end that is connected to the trunk region, with ~~a~~ the plurality of branches extending on at least one lateral side of the trunk region, the flex circuit having an inner skin-facing side and an outer side;

a plurality of electrode elements disposed on the inner side of the flex circuit along the branches of the flex circuit, each of the electrode elements having a conductive plate that is connected to the flex circuit in an electrically conducting manner, and a dielectric layer positioned to face the skin of the patient; and

a top, covering layer disposed on the outer side of the flex circuit, the covering layer being sized to cover the branches of the flex circuit and to overlap spaces between the branches, the covering layer having adhesive on a skin-facing side thereof by means of which the covering layer can be adhered to the patient's skin through the spaces between the branches,

wherein the covering layer is slotted to define a plurality of fingers overlying the branches of the flex circuit so that the fingers of the covering layer can move independently of each other as branches of the flex circuit flex independently of each other.

2. The electrode apparatus of claim 1, further comprising a plurality of conductive hydrogel discs wherein each of the conductive hydrogel discs is attached to a skin-facing side of a respective electrode element.

3. The electrode apparatus of claim 2, further comprising a plurality of gel barriers, wherein each of the gel barriers surrounds a respective one of the hydrogel discs.

4. The electrode apparatus of claim 1, further comprising a foam layer disposed on the inner side of the flex circuit, wherein the foam layer is configured to cover at least a portion of the trunk region of the flex circuit and at least a portion of the branches of the flex circuit, and leave the electrode elements uncovered.

5. The electrode apparatus of claim 4, further comprising a skin-level adhesive layer disposed on a skin-facing side of the foam layer.

6. The electrode apparatus of claim 5, wherein the skin-level adhesive layer has a configuration that follows the configuration of the flex circuit, with branches and trunk portions of the skin-level adhesive layer being wider than corresponding portions of the flex circuit so as to overlap spaces between the branches of the flex circuit.

7. The electrode apparatus of claim 1, wherein more electrode elements are attached to branches of the flex circuit that are closer to the longitudinal center of the trunk than are attached to branches of the flex circuit that are ~~farther from~~ closer to the longitudinal ends of the trunk.

8. The electrode apparatus of claim 1, wherein the trunk shifts back and forth in the lateral direction as it extends in the longitudinal direction.

9. The electrode apparatus of claim 1, wherein the trunk extends in the longitudinal direction in a straight manner.

10. The electrode apparatus of claim 1, further comprising a skin-level adhesive layer disposed on the inner side of the flex circuit.

11. The electrode apparatus of claim 10, wherein the skin-level adhesive layer has a configuration that follows the flex circuit, with branches and trunk portions of the skin-level adhesive layer being wider than corresponding portions of the flex circuit so as to overlap spaces between the branches of the flex circuit.

12. The electrode apparatus of claim 10, wherein the skin-level adhesive layer is attached directly to the inner side of the flex circuit.

13. The electrode apparatus of claim 1, wherein the flex circuit has a respective plurality of the branches extending on each lateral side of the trunk region.

14. The electrode apparatus of claim 1, wherein the flex circuit is configured so that no more than three paths emanate from any intersection on the flex circuit.

15. The electrode apparatus of claim 1, wherein the flex circuit is configured so that all segments of the flex circuit are straight.

16. The electrode apparatus of claim 1, further comprising an electrical cable that terminates on the flex circuit, wherein segments of the flex circuit near the distal end of each branch are thinner than at least some of the segments of the flex circuit that are adjacent to the electrical cable.