

APPARATUS AND METHOD OF DETERMINING PLACEMENT OF A TUBE

TECHNICAL FIELD

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The present disclosure relates broadly to an apparatus for determining placement of a tube and a method of determining placement of a tube.

BACKGROUND

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Nutritional supplementation via nasogastric tube (NGT) is provided for individuals who have difficulty consuming orally. The application of a nasogastric tube involves the insertion of a nasogastric tube through the nose, past the throat, and down into the stomach of the individual.

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To determine correct placement of the nasogastric tube, a chest X-ray may be performed after the insertion of nasogastric tube to confirm its position in the stomach. A chest X-ray has been regarded as the gold standard in verifying correct nasogastric tube placement. However, chest X-rays exposes the individual to unnecessary radiation as some
20 individuals may need several rounds of X-ray daily to check for placement if there is no gastric content aspirated. Frequent exposure to X-ray radiation is a hazard to health. In addition, frequent X-rays results in additional costs incurred by the individual.

Alternatively, confirmation of correct nasogastric tube insertion/placement also
25 includes a smooth insertion of the nasogastric tube or absence of coughing or respiratory distress during the insertion or placement procedure.

A 'whoosh test' may also be conducted to determine if the nasogastric tube has been inserted or placed correctly. In such a 'whoosh test', auscultation over the epigastria is
30 conducted while injecting air down the nasogastric tube. The presence of gurgling sound is indicative of air entering the stomach and is thus determinant of the nasogastric tube being in the correct position. However, auscultation was deemed obsolete as it is subject to the judgment of the practitioner. The presence of gurgling sound may not be distinguishable to inexperienced practitioners, in particular e.g. student nurses.

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As a further alternative, an aspiration test may be conducted where gastric fluid is drawn from the stomach and tested with e.g. pH paper to determine its acidity. Correct placement of the tube is determined should the fluid drawn from the stomach be determined to be acidic. However, there may be insufficient gastric fluid aspirated for testing. In addition, the pH acidity level of the gastric content of some individual(s) may not show up clearly with pH papers. This could be due to medications ingested by the individual or special diets of the individual. Further, in the event that the aspiration test is not successful on the first attempt, time is wasted with the current practice of repositioning subject and repeating the aspiration at a later time.

Indeed, none of the above approaches has been proven to be reliable or cost-effective in determining correct placement of a nasogastric tube. Incorrect placement of nasogastric tube has resulted in many complications such as e.g. aspiration pneumonia and other lung infections.

Thus, there is a need for an apparatus for determining placement of a tube and a method of determining placement of a tube that seeks to overcome or ameliorate the limitations of existing methods and provide a safe, fast and accurate way of detecting nasogastric tube placement.

SUMMARY

In accordance with an aspect, there is provided an apparatus for determining a placement of a tube, the apparatus comprising a fluid discharge module for discharging fluid into a first end of the tube; a sensor module for capturing sound produced at an approximate vicinity of the second end of the tube; and a processing unit for processing the sound to obtain one or more parameters; said one or more parameters for determining the placement of the tube.

The apparatus may further comprise the fluid discharge module being configured to discharge fluid with a constant flow rate for a first duration of time.

The flow rate may be any one of 5 ml/s, or 10 ml/s, or 15 ml/s, or 20 ml/s, or 25 ml/s, or 30 ml/s, or 35 ml/s, or 40 ml/s, or 45 ml/s, or 50 ml/s.

The first duration of time may be any one of 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0s.

5 The apparatus may further comprise the fluid discharge module being configured to push air into the first end of the tube.

10 The apparatus may further comprise the fluid discharge module being configured to push a plunger of a fluid containing vessel to discharge air out from the fluid containing vessel through a nozzle of the fluid containing vessel, said nozzle coupled to the first end of the tube.

The fluid discharge module may further comprise a holder assembly for maintaining the fluid containing vessel in a fixed position.

15 The fluid discharge module may further comprise a pusher assembly for providing a force on the plunger end of the fluid containing vessel.

20 The pusher assembly may further comprise a pusher aligned along a same longitudinal axis as the plunger.

The pusher assembly may further comprise the pusher being configured to apply on the plunger end of the fluid containing vessel, an average pressure from about 31.5 kPa to about 34.2 kPa.

25 The pusher assembly may further comprise an elastic element capable of being loaded; wherein releasing the elastic element from a loaded state provides the force on the plunger end of the fluid containing vessel.

30 The fluid discharge module may further comprise a signalling means for detecting the movement or position of the pusher and for signalling the processing unit based on the detected movement or position.

35 The pusher may further comprise a magnet such that the magnet is capable of moving in tandem with the pusher; and the signalling means may further comprise a magnetic switch for interacting with the magnet.

The signalling means may be configured to transmit a signal to the processing unit to trigger the capturing of sound based on the detected movement or position of the magnet.

5 The sensor module may further comprise an audio receiver for receiving sound.

The sensor module may further comprise a stethoscope for receiving the sound.

10 The sensor module may be configured to be capable of transmitting the captured sound to the processing unit.

15 The apparatus may further comprise the fluid discharge module and sensor discharge module being configured to synchronise the discharge of fluid into the first end of the tube with the capturing of sound produced at the approximate vicinity of the second end of the tube.

The apparatus may further comprise the processing unit being further configured to record the sound.

20 The apparatus may further comprise the processing unit being configured to record the sound over a second duration of any one of 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s, or 5.0

25 The apparatus may further comprise the processing unit being configured to obtain one or more frequencies of the sound and associated powers corresponding to the one or frequencies of the sound.

30 The apparatus may further comprise the processing unit being further configured to apply a digital signal processing technique to obtain the one or more frequencies and associated powers corresponding to the one or more frequencies of the sound.

The apparatus may further comprise the processing unit being configured to apply a Fast Fourier Transform to the sound.

35 The apparatus may further comprise the processing unit being further configured to obtain a total power of the one or more frequencies of the sound.

The apparatus may further comprise the processing unit being further configured to obtain a total power of a subset of the one or more frequencies of the sound.

5 The subset of the one or more frequencies of the sound may comprise frequencies from a critical frequency range.

The critical frequency range may be from 80 Hz to 500 Hz.

10 The processing unit may be further configured to obtain the total power of the subset, comprising obtaining a sum of powers in the subset which are at least of a threshold power.

The threshold power may be 1 mW.

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The processing unit may be further configured to obtain a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one or more frequencies of the sound.

20 The processing unit may be further configured to determine a correct placement of the tube if the percentage is more than or equal to a threshold percentage.

The threshold percentage may be 12.5%.

25 The apparatus may further comprise output means for providing a visual and/ or audio output signal to indicate correct or incorrect placement of the tube.

In accordance with another aspect, there is provided a method of determining a placement of a tube, the method comprising discharging fluid into a first end of the tube
30 with a fluid discharge module; capturing sound produced at proximate the second end of the tube with a sensor module; processing the sound to obtain one or more parameters with a processing unit; and determining the placement of the tube based on the one or more parameters.

35 The step of discharging fluid may further comprise discharging fluid with a constant flow rate for a first duration of time.

The flow rate may be any one of 5 ml/s, or 10 ml/s, or 15 ml/s, or 20 ml/s, or 25 ml/s, or 30 ml/s, or 35 ml/s, or 40 ml/s, or 45 ml/s, or 50 ml/s.

5 The first duration of time may be any one of 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0s.

The step of discharging fluid may further comprise pushing air into the first end of the tube by the fluid discharge module.

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The step of pushing air into the first end of the tube may further comprise pushing a plunger of a fluid containing vessel to discharge air out from the fluid containing vessel through a nozzle of the fluid containing vessel, said nozzle coupled to the first end of the tube.

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The method may further comprise maintaining the fluid containing vessel in a fixed position using a holder assembly.

20 The step of pushing the plunger may comprise providing a force on the plunger end of the fluid containing vessel with a pusher assembly.

The pusher assembly may comprise a pusher aligned along a same longitudinal axis as the plunger.

25 The step of pushing the plunger may comprise applying an average pressure from about 31.5 kPa to about 34.2 kPa on the plunger end of the fluid containing vessel.

30 The step of pushing the plunger may further comprise loading an elastic element of the pusher assembly; and releasing the elastic element from the loading; wherein releasing the elastic element provides the force on the plunger end.

The method may further comprise detecting the movement or position of the pusher; and signalling the processing unit based on the detected movement or position.

The step of detecting the movement or position of the pusher may comprise providing a magnet to move in tandem with the pusher; and providing a magnetic switch for interacting with the magnet.

5 The step of signalling the processing unit based on the detected movement or position may comprise transmitting a signal to the processing unit to trigger the capturing of sound based on the detected movement or position of the magnet.

10 The step of capturing sound may further comprise receiving sound with an audio receiver.

The step of receiving sound may further comprise receiving the sound with a stethoscope.

15 The method may further comprise transmitting the captured sound to the processing unit.

20 The step of discharging fluid into a first end of the tube with a fluid discharge module and the step of capturing sound produced at an approximate vicinity of the second end of the tube with a sensor may be synchronised.

The method may further comprise recording the sound with the processing unit.

25 The step of recording the sound may comprise recording the sound over a second duration of any one of 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s, or 5.0 s.

30 The step of processing the sound to obtain one or more parameters may comprise obtaining one or more frequencies of the sound and associated powers corresponding to the one or more frequencies of the sound.

The step of obtaining the one or more frequencies and associated powers corresponding to the one or more frequencies of the sound may comprise applying a digital signal processing technique.

35 The digital signal processing technique may comprise Fast Fourier Transform.

The method may further comprise obtaining a total power of the one or more frequencies of the sound.

5 The method may further comprise obtaining a total power of a subset of the one or more frequencies of the sound.

The subset of the one or more frequencies of the sound may have frequencies from a critical frequency range.

10 The critical frequency range may be from 80 Hz to 500 Hz.

The step of obtaining a total power of the subset may comprise obtaining a sum of associated powers in the subset which are at least a threshold power.

15 The threshold power may be 1 mW.

The method may further comprise obtaining a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one or more frequencies of the sound.

20 The step of determining a correct placement of the tube may comprise obtaining a percentage value of more than or equal to a threshold percentage.

The threshold percentage may be 12.5%.

25 The method may further comprise providing a visual and/ or audio output signal to indicate correct or incorrect placement of the tube.

30 In accordance with another aspect, there is provided a method of determining a placement of a tube, the method comprising discharging fluid into a first end of the tube with a fluid discharge module; capturing sound produced at proximate a second end of the tube with a sensor module; processing the sound with a processing unit to obtain one or more frequencies of the sound and associated powers corresponding to the one or frequencies of the sound; and determining the placement of the tube based on a total
35 power of a subset of the one or more frequencies of the sound over a total power of the one or more frequencies of the sound.

The subset of the one or more frequencies of the sound may have frequencies from a critical frequency range.

- 5 The total power of a subset of the one or more frequencies of the sound may comprise a sum of associated powers in the subset which are at least a threshold power.

 The method may further comprise obtaining a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one
10 or more frequencies of the sound.

 The step of determining a correct placement of the tube may comprise obtaining a percentage value of more than or equal to a threshold percentage.

- 15 In accordance with another aspect, there is provided a non-transitory computer readable storage medium having stored thereon instructions for instructing a processing module of an apparatus to execute a method of determining placement of a tube, the method comprising, discharging fluid into a first end of the tube with a fluid discharge module; capturing sound produced at proximate the second end of the tube with a
20 sensor module; processing the sound to obtain one or more parameters with a processing unit; and determining the placement of the tube based on the one or more parameters.

- In accordance with another aspect, there is provided a non-transitory computer
25 readable storage medium having stored thereon instructions for instructing a processing module of an apparatus to execute a method of determining placement of a tube, the method comprising, discharging fluid into a first end of the tube with a fluid discharge module; capturing sound produced at proximate a second end of the tube with a sensor module; processing the sound with a processing unit to obtain one or more frequencies
30 of the sound and associated powers corresponding to the one or frequencies of the sound; and determining the placement of the tube based on a total power of a subset of the one or more frequencies of the sound over a total power of the one or more frequencies of the sound.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Fig. 1 is a schematic block diagram of an apparatus for determining placement of a tube in an example embodiment.

Fig. 2A is a schematic perspective view drawing of an apparatus for determining placement of a tube in an example embodiment.

Fig. 2B is another schematic perspective view drawing of the apparatus for determining placement of a tube in the example embodiment.

Fig. 2C is a schematic front view drawing of the apparatus for determining placement of a tube in the example embodiment.

Fig. 2D is a schematic top view drawing of the apparatus for determining placement of a tube in the example embodiment.

Fig. 2E is a schematic side view drawing of the apparatus for determining placement of a tube in the example embodiment.

Fig. 2F is another schematic side view drawing of the apparatus for determining placement of a tube in the example embodiment.

Fig. 3 is a photograph of an apparatus for determining placement of a tube in an example embodiment.

Fig. 4 is a photograph of a fluid discharge module in an example embodiment.

Fig. 5 is a photograph of a sensing module in an example embodiment.

Fig. 6 is a photograph of a processing module in an example embodiment.

Fig. 7A shows a schematic perspective view drawing of an apparatus for determining placement of a tube during fluid discharge in an example embodiment.

5 Fig. 7B shows another schematic perspective view drawing of the apparatus for determining placement of a tube during fluid discharge in the example embodiment.

Fig. 7C shows a schematic top view drawing of the apparatus for determining placement of a tube during fluid discharge in the example embodiment.

10 Fig. 7D shows a schematic front view drawing of the apparatus for determining placement of a tube during fluid discharge in the example embodiment.

15 Fig. 7E shows a schematic side view drawing of the apparatus for determining placement of a tube during fluid discharge in the example embodiment.

Fig. 7F shows another schematic side view drawing of the apparatus for determining placement of a tube during fluid discharge in the example embodiment.

20 Fig. 8 shows a schematic diagram for illustrating a method of using an apparatus for determining placement of a tube 2802 in an example embodiment.

Fig. 9 shows a photograph depicting a front view of an exposed portion of a torso of a human subject.

25 Fig. 10 is a flowchart illustrating a decision matrix implemented in a processing module in an example embodiment.

30 Fig. 11 is a flowchart illustrating a method of determining placement of a tube in an example embodiment.

Fig. 12 is a schematic drawing of a computer system suitable for implementing an example embodiment.

35 Fig. 13 is a schematic drawing of a communication device suitable for implementing an example embodiment.

DETAILED DESCRIPTION

Exemplary, non-limiting embodiments of the present application provide an apparatus for determining placement of a tube and a method for determining placement
5 of a tube.

Fig. 1 is a schematic block diagram of an apparatus for determining placement of a tube 100 in an example embodiment. The apparatus for determining placement of a tube 100 comprises a fluid discharge or injection module 102, a sensing module 104
10 and a processing module 106. The fluid discharge module 102 and sensing module 104 are each coupled respectively to the processing module 106. The fluid discharge module 102 functions to discharge fluid e.g. air. A characteristic sound signal may be produced through the discharge of fluid by the fluid discharge module 102. The sensing module 104 functions to pick up the presence of or receive sound signals. Any sound
15 signal which is detected or received by the sensing module 104 is transmitted to the user interface or processing module 106. The processing module 106 functions to capture, record and analyse the signal detected by the sensing module 104.

In the example embodiment, the fluid discharge module 102 may be further
20 connected to a first end of a tube. The fluid discharge module 102 is configured to discharge the fluid e.g. air through the first end of the tube, which may then cause a characteristic sound signal to be produced at e.g. a second or other end of the tube. The sensing module 104 is positioned near or proximate an estimated position of the second or other end of the tube and is configured to pick up the presence of or receive
25 sound signals. Sound which is detected by the sensing module 104 is transmitted to the processing module 106.

The processing module 106 is configured to capture, record and analyse the sound detected by the sensing module 104 to determine if the sound has characteristics
30 for it to be determined as a characteristic sound signal.

Based on the presence of the characteristic sound signal, the processing module 106 of the apparatus 100 is able to determine a location of the second end of the tube, and therefore determine if the tube has been correctly placed.

Fig. 2A is a schematic perspective view drawing of an apparatus 200 for determining placement of a tube in an example embodiment. Fig. 2B is another schematic perspective view drawing of the apparatus 200 in the example embodiment. Fig. 2C is a schematic front view drawing of the apparatus 200 when viewed in the direction from numeral 202 in Fig. 2A. Fig. 2D is a schematic top view drawing of the apparatus 200. Fig. 2E is a schematic side view drawing of the apparatus 200 when viewed in the direction from numeral 204 in Fig. 2A. Fig. 2F is a schematic side view drawing of the apparatus 200 when viewed in the direction from numeral 206 in Fig. 2A.

Description of the apparatus 200 below will be made with reference to the drawings Fig. 2A to 2F.

In the example embodiment, the apparatus for determining placement of a tube 200 comprises a fluid discharge module 208 coupled to a processing module 210. The fluid discharge module 208 is mated to a receiving surface (not shown) on the processing module 210 via side guides 212, 214 which guide the fluid discharge module 208 into position with respect to the processing module 210. The fluid discharge module 208 is secured to the processing module 210 by fastening means, for example, wing nut fasteners 216, 218. The fluid discharge module 208 is connected electrically to the processing module 210 via a cable (not shown) which can be plugged into a port 220 provided on the processing module 210. In alternative embodiments, the fluid discharge module 208 may be separated from the processing module 210 i.e., as a stand-alone apparatus.

The fluid discharge module 208 functions to deliver/ discharge fluid e.g. gas or liquid in a controlled manner. The fluid discharge module 208 is capable of delivering fluid from a fluid containing vessel at a substantially constant pressure and flow rate. In the example embodiment, the fluid discharge module 208 is capable of discharging fluid from the fluid-containing vessel (e.g., a syringe) at a flow rate of 20 ml/s. In addition, the fluid discharge module 208 is capable of producing an average pressure of about 31.5 kPa to about 34.2 kPa on the fluid-containing vessel per discharge. In the example embodiment, the fluid discharge module 208 comprises a holder assembly 222, a pusher assembly 224, a rail assembly 226 and a signalling means in the form of e.g. a magnetic switch housed within a magnetic switch holder 228, each coupled respectively to a base 230.

The holder assembly 222 functions to receive a fluid-containing vessel (e.g. syringe) and comprises a holder stand 232, a holder clamp 234 coupled to the holder stand 232 via a hinge 236, and a lock 238 coupled to the holder stand 232. The holder clamp 234 is configured to swing about a pivot between an open and a closed configuration. In the closed configuration, the holder clamp 234 and the holder stand 232 forms a receiving surface 240 for receiving and maintaining a vessel in a fixed, horizontal position. In other words, the vessel can be secured and held in the holder assembly 222 when the holder clamp 234 is in the closed position. The holder clamp 234 and the lock 238, e.g. quick-release lock, secure the vessel in position.

In the open configuration, the holder clamp 234 swings open to allow the vessel to be mounted or dismounted from the holder assembly 222. In the example embodiment, the fluid-containing vessel is a syringe. In the example embodiment, the receiving surface 240, formed when the holder clamp 234 is in the closed configuration, is a circular opening. The circular opening in the example embodiment is dimensioned to snugly fit around an external circumference of the syringe.

The holder assembly 222 may be provided with adapters for receiving syringes of various standard volumes ranging from 10 ml to 50 ml, each of the standard syringes having a different standard external circumferential dimension/size. In a preferred embodiment, the volume of syringe to be used is 10 ml.

The pusher assembly 224 functions to provide a force on a e.g. plunger end of a fluid-containing vessel e.g. a syringe, causing fluid to be expelled from the fluid-containing vessel. In the example embodiment, the pusher assembly 224 is configured to apply a substantially constant force, causing fluid to be delivered at a substantially constant output pressure. The pusher assembly 224 may be configured to apply an average pressure of about 31.5 kPa to about 34.2 kPa on a fluid-containing vessel e.g. plunger end of a syringe, for a period of about 3.0 seconds to about 5.0 seconds.

The pusher assembly 224 comprises a pusher stand 242 for receiving a pusher/pusher member 244 and maintaining the pusher 244 in a fixed and substantially horizontal position. The pusher 244 is an elongated member having a circular cross section and is movable with respect to the pusher stand 242 along a push path which is along a longitudinal axis of the pusher 244. An elastic element (not shown) in the form of e.g. a spring, is provided within the pusher 244, for actuating the pusher 244 along

the push path. In operation, the elastic element is pre-configured in a loaded state (e.g. a contracted/extended state) by a user. A button 268 is provided on the pusher 244 for triggering actuation of the pusher 244. Actuation of the button 268 causes the elastic element to be released from its loaded state to an unloaded state, which thereby provides a translational driving force to actuate the pusher 244 to move along the push path along the longitudinal axis of the pusher 244.

In the example embodiment, the pusher 244 is further coupled to a contact pad 246 and a securing disk 248 is provided for securing the contact pad 246 to the pusher 244, and to secure the pusher 244 to the rail assembly 226. The contact pad 246 engages the fluid containing vessel when the pusher assembly 224 applies a force on the e.g. plunger end of the fluid containing vessel.

The rail assembly 226 functions to guide and maintain linear translation of the pusher 244 along the push path. In turn, this ensures that the plunger end of the fluid containing vessel translates linearly along the push path. The rail assembly 226 comprises a rail 250, a holder 252 coupled to the rail 250 and a bracket 254 coupled to the holder 252. Ball bearings are provided in the holder 252 to facilitate the linear movement of the holder 252 along the rail 250.

In the example embodiment, the holder 252 is coupled to the securing disk 248 of the pusher assembly 224 via the bracket 254. The coupling of the securing disk 248 to the magnet holder 252 is to facilitate and maintain linear movement/displacement of the pusher 244 and in turn, the plunger end of the fluid containing vessel. Movement/displacement of the holder 252 along the rail 250 in a first direction towards the holder assembly 222 causes the disk 248, the contact pad 246 and the pusher 244 of the pusher assembly 224 to move/displace in tandem in the same direction. With a fluid-containing vessel (e.g. syringe) received or mounted on the holder assembly 222, the movement of the pusher 244 in the first direction (along the longitudinal axis of the pusher towards the holder assembly 222) causes the pusher 244 to apply a force on the plunger end of the fluid-containing vessel, which will cause fluid to be delivered from an outlet on the fluid-containing vessel (e.g. a nozzle of a syringe).

In the example embodiment, no adjustment is required to set the flow rate and output pressure exerted by the pusher. The pusher is pre-configured or pre-calibrated to deliver the desired output pressure and flow rate such that sound signals with the

correct characteristics/ properties are produced if the tube is correctly placed or inserted. In the example embodiment, the pusher is configured to be replaceable. The pusher may be replaced when the sound waveform produced by the pusher appears abnormal, e.g., deviates from a normal sound waveform of a characteristic sound signal. Based on
5 usage data on an exemplary prototype, when a tube is correctly placed, a pre-calibrated pusher is capable of delivering the desired output pressure and flow rate, such that the characteristic sound signal is produced even after 150 applications.

In the example embodiment, the holder 252 also houses a circular magnet.
10 Movement/displacement of the pusher 244 in the first direction also causes the circular magnet housed within the magnet holder 252 to move/displace in tandem in the same direction along the rail 250. In other words, movement of the pusher 244 results in similar movement of the circular magnet. It will be appreciated that the holder may also be referred to as a magnet holder.

15 The magnet interacts with the magnetic switch such that based on the movement/configuration of the magnet housed within the holder 252, the magnetic switch is further configured to transmit a signal to the processing module 210 to start or stop capturing sound signals. Thus, the signalling means detects the movement or
20 position of the pusher and signals the processing unit based on the detected movement or position.

In the example embodiment, the magnetic switch is configured to transmit a signal to the processing module 210 to start capturing/recording sound signals upon
25 detecting movement of the pusher. That is, the start of discharge of fluid from the fluid containing vessel and the start of recording of sound signals are synchronised. In alternative embodiments, a slight delay may be built in such that the sound signals are recorded a delayed period after the magnetic switch signals the processing unit of the movement of the pusher.

30 The signalling means in the form of the magnetic switch housed in the magnetic switch holder 228 is further connected to a processing module and/or external power source via a cable (not shown).

35 In the example embodiment, the processing module 210 is configured to receive, record and analyse signals detected by a sensing module (compare 104 of Fig. 1) which

can be connected to the processing module 210. The processing module 210 comprises a housing 256, a display screen 258 provided on a top surface of the housing 256 and side guides 212, 214 coupled to the housing 256. The housing 256 comprises circuitry components (not shown) for recording, processing and analysing signals, storage of recorded signals, and displaying of information on the screen 258. In the example embodiment, a central processing unit ARM Cortex M3 (LPC1788) processor is provided within the housing.

The display screen 258 functions to display parameters such as frequency range and duration of the recording. The screen may also allow for the display of waveforms such that functions such as system diagnostics, waveform analysis and sensitivity setups can be performed. In essence, a user is allowed to input or modify the parameters by viewing the information displayed on the screen 258. The screen 258 is also capable of displaying analysis outcomes. For example, when the recorded signal meets certain predetermined criteria after analysis, the screen 258 is configured to indicate accordingly and e.g. display the word "PASS", confirming a positive result. When the signal does not meet the predetermined criteria, the screen 258 displays e.g. the word "FAIL" to indicate a negative result. In alternative example embodiments, Light Emitting Diodes (LED) indicators may also be provided for indicating if the signal meets the predetermined criteria. In the example embodiment, the screen 258 is a liquid crystal display (LCD) touch screen. In alternative embodiments, the screen 258 may be a dot-matrix screen or LED display with buttons. Keypads, joysticks etc may also be provided in addition to the screen 258 for allowing a user to provide input to the processing module 210.

In the example embodiments, the processing module 210 is also capable of producing sound, e.g. beeping sound or recorded voice messages to inform a user of the analysis outcomes or to instruct a user how to operate the apparatus 200.

Thus, in the example embodiment, the apparatus 200 for determining placement of a tube comprises output means for providing visual and/or output signals to indicate the correct or incorrect placement of the tube.

In addition to displaying data and outcomes on the screen 258, data stored in the processing module 210 can be exported to an external apparatus e.g. computer, for storage or analysis. A port 266 is provided on the housing 256 of the processing module

210 to allow data communications with an external apparatus, for example, an external storage apparatus in the form of a Micro SD (Secure Digital) card.

5 The side guides 212, 214 are capable of receiving a separate apparatus e.g. a fluid discharge module 208 such that the fluid discharge module 208 is mated and secured to the processing module 210. A first connection port 260 is provided on the housing 256 for allowing e.g. cabled connection to the fluid discharge module 208. A second connection port 262 is provided on the housing 256 for allowing e.g. cabled connection to a sensing module (compare 104 of Fig. 1). An audio jack 264 is provided
10 on the housing 256 for allowing connections to audio apparatus e.g. earphone, speaker, amplifier etc.

In the example embodiment, the fluid discharge module 208 can be a stand-alone unit. That is, the fluid discharge module 208 can be detached from the processing
15 module 210 and is not constrained in operation by e.g. physical connections to the processing module 210.

In the example embodiment, a separate power module (not shown) may be provided. The power source may be, for example, one or more rechargeable batteries
20 and/or disposable energy sources. The apparatus 200 can thus be portable to a user. By portable, it is meant, among other things, that the apparatus 200 is capable of being transported relatively easily. In alternative embodiments, the apparatus 200 comprises an adapter port for connection to an external power source.

25 Fig. 3 is a photograph of a apparatus for determining placement of a tube 300 in an example embodiment. The apparatus 300 comprises a processing module 302 coupled to a sensing module 304 and a fluid discharge module 306.

In operation, a button (compare 268 of Fig. 2A) on the fluid discharge module
30 306 is depressed or actuated to trigger the fluid discharge module 306 to discharge fluid e.g. air from a syringe 308 mounted on the fluid discharge module 306. The fluid discharge module 306 causes fluid to be discharged from the syringe 308 by applying a force on its plunger. The syringe 308 is connected to a tube having a first (proximal) end and a second (distal) end. The first (proximal) end of the tube is connected to the
35 syringe 308 via its nozzle. Fluid in the syringe 308 is discharged from the first (proximal) end of the tube to exit from the second (distal) end of the tube. The fluid in the syringe is

dispensed over a time duration of about 0.5 seconds at a flow rate of 20 ml/s. That is, 10 ml of fluid is being dispensed. The second (distal) end of the tube may be situated at a target location which is not visible to the naked eye e.g. in the stomach of a subject. The tube may be a flexible tube such as a nasogastric tube. The fluid discharge module 306 is configured to discharge fluid e.g. air into the tube such that a sound is produced at the distal end of the tube. The sound produced by the discharge of fluid has a characteristic amplitude, pitch and frequency which can be detected by the sensing module 304.

The sensing module 304 functions to detect and capture detected sound signals and transmits them to the processing module 302 for further processing and analysis. In operation, in the example embodiment, the sensing module 304 is placed in a location proximate the second (distal) end of the tube. Captured signals are transmitted to the processing module 302 which records and analyses the captured signals. In the example embodiment, the processing module 302 is configured to trigger recording of sound signals at substantially the same time as the trigger for the fluid discharge module 306 to discharge fluid. In the example embodiment, sound signals are recorded for a duration of e.g. 5 seconds. Signal processing algorithms are applied on the recorded sound signals to analyse the recorded sound signals using a processing time frame set at a time frame interval of e.g. 0.5 seconds to determine if the recorded sound signals satisfy criteria for the sound to be considered a characteristic sound signal. In the example embodiment, the recorded sound signals are subjected to Fast Fourier Transform (FFT) processing and digital signal filtering algorithms. By determining the presence of the characteristic sound signal, the sensing module 304 is able to determine the location of the second (distal) end of the tube where the characteristic sound signal is produced. In so doing, correct placement of the tube can be determined.

The processing module 302 is electrically connected to the fluid discharge module 306 and the sensing apparatus 304 respectively via a first connection port 310 and a second connection port 312 provided on the processing module 302. The processing module 302 may optionally comprise an earphone 314 for allowing a user to listen to the recorded sound signal.

In the example embodiment, the fluid discharge module 306 may be attached to the processing module 302 to form a single integrated unit. The fluid discharge module 306 may also be detached from the processing module 302, such that it is not constrained in operation.

In the example embodiment, the apparatus 300 comprises a power source. The power source may be, for example, one or more rechargeable batteries and/or disposable energy sources. The apparatus 300 can thus be portable to a user. By portable, it is meant, among other things, that the apparatus 300 is capable of being transported relatively easily. The apparatus may also be connected to an external power source via an adapter. In the example embodiment, the apparatus for determining placement of a tube 300 further comprises a port 316 to allow data communications with an external apparatus, such as, for example an external storage apparatus in the form of a Secure Digital (SD) card, or more particularly, a micro SD card.

Fig. 4 is a photograph of a fluid discharge module 400 in an example embodiment. The fluid discharge module 400 functions to discharge fluid e.g. air from a syringe 412 in a controlled manner, where the flow rate and pressure of the discharged fluid expelled from the syringe 412 is maintained within e.g. a predefined range. The fluid discharge module 400 comprises a base 402. The fluid discharge module 400 further comprises a syringe holder 404, a pusher assembly 406, a rail assembly 408 and a signalling means in the form of the magnetic switch housed in the magnetic switch holder 410, each respectively coupled to the base 402. The syringe holder 404 sits on the base 402 and functions to support the syringe 412 in an e.g. fixed, horizontal position. The syringe 412 comprises a barrel 414 containing fluid e.g. air, a nozzle 416 for allowing fluid to exit from the barrel 414, and a plunger 418 for pushing the fluid out from within the barrel 414 via the nozzle 416. The syringe holder 404 clamps and secures the barrel 414 in a fixed position, thus preventing any movement of the barrel 414.

In the example embodiment, the pusher assembly 406 functions to provide a pushing force to actuate the plunger 418, causing fluid to be discharged or expelled from the nozzle 416 in a controlled manner. The pusher assembly 406 comprises a pusher holder 420 which is coupled to and sits on the base 402. The pusher assembly 406 further comprises a pusher 422 held by the pusher holder 420. A contact pad 424 is coupled to the pusher 422, said contact pad for engaging the plunger 418. The pusher assembly 406 further comprises a securing disk 426 for securing the pusher 422 to the rail assembly 408. In operation, the pusher 422, contact pad 424, plunger 418 of the syringe 412 are aligned along a same axis such that movement of the pusher 422 along the axis in the direction of the syringe 412 causes the plunger 418 to move in the same

direction. That is, a pushing force applied by the pusher 422 is transmitted to the plunger 418 of the syringe 412 via the contact pad 424.

In the example embodiment, the rail assembly 408 sits on the base 402 and comprises a rail 428 and a guide member/ holder 430 which is movable along the rail 428. The rail assembly 408 is further coupled to the magnetic switch holder 410 and the guide member or holder 430 is further coupled to the securing disk 426 of the pusher assembly 406. Movement of the pusher 422 in the first direction in turn causes the pusher 422 of the pusher assembly 406 to move simultaneously in the same first direction. As the pusher 422 is aligned axially with the plunger 418, a pushing force is applied on the plunger 418, causing fluid to be delivered from the nozzle 416 of the syringe 412.

In the example embodiment, the holder 430 also houses a circular magnet which interacts with the magnetic switch housed within the magnetic switch holder 410. In operation, translation of the pusher 422 along the axis in the direction of the syringe 412 is triggered by pressing a button 436 provided on the pusher 422. Pressing of the button 436 changes the configuration/state of an elastic member (not shown) within the pusher 422, thereby releasing the elastic potential energy stored in the elastic member to produce a translational driving force to actuate the pusher 422. As the circular magnet within the magnet holder 430 moves simultaneously in the same first direction, the magnetic switch in the magnetic switch holder 410 detects the movement of the circular magnet housed within the magnet holder 430 and feeds back to a processing module (compare 302 of Fig. 3) the position of the circular magnet. Based on the relative position of the circular magnet, the position of the plunger 418 (or pusher 422, or contact pad 424, or securing disk 426) is known, allowing the processing module (compare 302 of Fig. 3) to determine the state of the apparatus, i.e., before or after expulsion of fluid from the syringe and accordingly trigger the recording of the sound. Thus, the signalling means detects the movement or position of the pusher and signals the processing unit based on the detected movement or position of the pusher.

In the example embodiment, the magnetic switch is further connected to an external power source or processing module (compare 302 of Fig. 3) via a cable 432. The fluid discharge module 400 may further comprise screw knobs 434 for securing the fluid discharge module 400 to a platform/ surface e.g. of a processing module (compare 302 of Fig. 3).

In the example embodiment, the syringe 412 may be coupled to a flexible tube (not shown) via the nozzle 416. The tube may be made of polyvinyl chloride (PVC) or silicon and is available in diameters such as 12 Fr, 14 Fr, and 16 Fr. The flexible tube may be a nasogastric tube for inserting into the stomach of a subject via the nose.

Fig. 5 is a photograph of a sensing module 500 in an example embodiment. The sensing module 500 functions to pick up or receive signals e.g. sound signals in the vicinity of the sensing module 500. The sensing module 500 comprises a probe 502 coupled to a grip 504. The probe 502 functions to detect the presence of any signals e.g. sound signals in the vicinity of the probe 502. The grip 504 is shaped to provide a firm hand grip for a user and also houses circuitry components, which comprises one or more electrical connections, for capturing sound in the vicinity and transmitting the sound signals to the processing module (compare 302 of Fig. 3) for processing.

The sensing module 500 is connected to the processing module (compare 302 of Fig. 3) via a cable 506 which is in electrical connection with the circuit components within the grip 504. In the example embodiment, the sensing probe functions substantially like an audio receiver for receiving sound. That is, the sensing or sensor module comprises an audio receiver in the form of e.g. an electronic stethoscope which picks up and receives sound signals. The sensing or sensor module 500 may further comprise transmitting means to transmit the sound signals to a separate processing apparatus e.g. a processing module (compare 302 of Fig. 3).

Fig. 6 is a photograph of a processing module 600 in an example embodiment. The processing module 600 comprises a housing 602, a display screen 604 provided on a top surface of the housing 602, and side guides 606, 608. The side guides 606, 608 are arranged for receiving and securing a fluid discharge module (compare 306 of Fig. 3) in position when the fluid discharge module is mated to the processing module 600. In the example embodiment, the screen is a LCD screen with touch screen functions. Operating parameters such as actuation and time duration for detecting or capturing sound can be input via the touch screen. Ports 610, 612, 614, 616 are provided on a front surface of the housing 602 for connection to external devices such as e.g. a fluid discharge module (compare 306 of Fig. 3) and a sensing module (compare 304 of Fig. 3).

Fig. 7A shows a schematic perspective view drawing of an apparatus for determining placement of a tube 700 during fluid discharge in an example embodiment. Fig. 7B shows another schematic perspective view drawing of the apparatus for determining placement of a tube 700 during fluid discharge in the example embodiment.

5 Fig. 7C shows a schematic top view drawing of the apparatus for determining placement of a tube 700 during fluid discharge in the example embodiment. Fig. 7D shows a schematic front view drawing of the apparatus for determining placement of a tube 700 during fluid discharge in the example embodiment. Fig. 7E shows a schematic side view drawing of the apparatus for determining placement of a tube 700 during fluid discharge

10 when viewed in the direction from numeral 702 in Fig. 7C. Fig. 7F shows a schematic side view drawing of the apparatus for determining placement of a tube 700 during fluid discharge when viewed in the direction from numeral 704 in Fig. 7C.

Description of the apparatus 700 below will be made with reference to the

15 drawings Fig. 7A to 7F.

In the example embodiment, a syringe 706 comprising a plunger 708, a barrel 710 and a nozzle 712 is mounted on a holder assembly 714 comprising a holder stand 716, a holder clamp 718 and a lock 720. The barrel 710 of the syringe 706 is held by the

20 holder stand 716 and the holder clamp 718. The lock 720 secures the barrel 710 in position and the syringe 706 is maintained in a horizontal position. The plunger 708 is pulled along the barrel 710 away from the nozzle 712 such that the barrel 710 is filled with fluid e.g. air.

In the example embodiment, a pusher assembly 722 comprises a pusher 724, a pusher stand 726, a disk 728 and a contact pad 730. The pusher 724 is aligned along a same longitudinal axis as the plunger 708. The pusher 724 further comprises a button 744 for triggering translation of the pusher 724 along the longitudinal axis. The pusher assembly 722 abuts the plunger 708 of the syringe 706 via the contact pad 730 of the

30 pusher 724. Once the syringe 706 is mounted in position, input parameters are entered into a processing module 732 via a touch screen 734. The input parameters may include e.g. recording duration and delay between pusher actuation and recording commencement. Once the input parameters are confirmed, the button 744 is depressed to trigger the translation of the pusher 724 in the direction of the plunger 708.

The securing disk 728 of the pusher assembly 722 is coupled to a magnet holder 738. The magnet holder 738 houses a magnet which interacts with a magnetic switch housed in a magnetic switch holder 736. As the pusher 724 and the securing disk 728 translate along the longitudinal axis of the plunger 708 in the direction 742, the magnet within the magnetic holder 738 also travels in tandem along the rail 740 in the direction 742. This causes the contact pad 730 to engage the plunger 708 as the pusher 724 actuates the plunger 708 in the direction 742. As the plunger 708 actuates in the direction 742, air is discharged from the barrel 710. As the magnet travels in the direction 742, the magnet holder 738 also moves in the direction 742. This movement is detected by the magnetic switch in the magnetic switch holder 736 which feedbacks to the processing module 732 the position/displacement of the pusher 724 and the securing disk 728. In turn, this provides an indirect measurement of the position/displacement of the plunger 708, which is in contact with the pusher 724.

The nozzle 712 may be connected to a first end of a tube (not shown). A second end of the tube is open to allow air to exit from the tube. Air contained in the barrel 710 can be discharged via the nozzle 712 into the first or connected end of the tube. The injection of air into the first end of the tube displaces the column of air already present in the tube, causing air to be discharged from the second or open end of the tube. In the example embodiment, the discharge of air from the second end of the tube produces a characteristic "swoosh" sound at the second end of the tube. The second end of the tube may be immersed in a body of fluid. In the example embodiment, the tube may be flexible e.g. a nasogastric tube.

Fig. 8 shows a schematic diagram 800 for illustrating an operation of an apparatus for determining placement of a tube 802 in an example embodiment. The apparatus 802 comprises a fluid discharge module 804 and a sensing module 806, each of which is coupled to a processing module 808. A syringe (compare 706 of Fig. 7) is mounted on the fluid discharge module 804. The nozzle (compare 712 of Fig. 7) of the syringe is further coupled to a first end of a nasogastric tubing 810. Prior to coupling with the fluid discharge module 804, a nasogastric intubation procedure is performed wherein the nasogastric tubing 810 is inserted into the stomach 812 of a subject 814 via the oesophagus 816. At the end of the nasogastric intubation procedure, a second end of the nasogastric tubing 810 should be situated in the stomach 812, if the nasogastric tubing 810 has been correctly inserted.

The apparatus for determining placement of a tube 802 is capable of detecting the location of the second end of the nasogastric tubing 810 in the subject 814 and determining whether the nasogastric tubing 810 has been correctly inserted. This is performed by triggering the fluid discharge module 804 to discharge air from the syringe (compare 706 of Fig. 7) into the first end of the nasogastric tubing 810. Air is discharged from the syringe at substantially constant pressure due to application of a substantially constant force by the fluid discharge module on the plunger of the syringe (compare 708 of Fig. 7). This causes air to be discharged from the second end of the nasogastric tubing, which is located within the subject. The discharge of air from the second end of the nasogastric tubing 810 produces a sound which can be detected by the sensing module 806. In the example embodiment, if the nasogastric tubing 810 is correctly inserted, air discharged from the fluid discharge module 804 produces a sound with characteristic properties. Some of these characteristic properties include an amplitude, power and frequency of the sound wave(s).

The probe (compare 502 of Fig. 5) of the sensing module 806 is placed over the stomach region of the subject 814 to detect presence of or capture sound signals. In particular, the probe seeks to detect sound signals produced when air of substantially constant pressure is injected into the stomach via the nasogastric tubing 810 using the fluid discharge module 804. The probe may be contacting the skin surface of the subject 814 over the stomach region or may be positioned above the stomach region without touching the subject 814. Sound signals detected or captured by the probe are transmitted to the processing module 808 which records and analyses the signals. In the example embodiment, the triggering of the processing module 808 to capture and record signals is configured to be synchronised with the triggering of the fluid discharge module 804 to discharge air. That is, the capture and record of signals by the sensing module 806 and processing module 808 is simultaneous or synchronised with the discharge of air by the fluid discharge module 804.

The processing module 808 processes the recorded sound signals using a programming algorithm comprising Fast Fourier Transform (FFT) techniques and digital signal filtering conditions. The processed signals are then further analysed using a decision matrix to determine whether the second end of the nasogastric tubing 810 is located in the correct position (i.e., the stomach 812 of the subject 814). If the second end of the nasogastric tubing 810 is located in the correct position, and it is determined as so by the algorithm and decision matrix, the processing module 808 will indicate with

an indicator light (e.g. green light) and/or a message showing "PASS" or the like. If the second end of the nasogastric tubing 810 is located in the wrong position, the user interface will indicate with an indicator light (e.g. red light or no light) and/or a message showing "FAIL" or the like.

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Fig. 9 shows a photograph depicting a front view of an exposed portion of a torso of a human subject. The torso is divided into a 3 by 3 grid using dotted lines. Markings "X" are used to indicate the positions for placing a probe (compare 502 of Fig. 5) of a sensing module (compare 500 of Fig. 5). Position A is located about 3 cm below the tip of the xiphoid process. The xiphoid process is a small cartilaginous extension of the lower part of the sternum and is an anatomical landmark which can be located by palpating the sternum. Position B is located at the midpoint of the epigastrium and umbilicus. The epigastrium and umbilicus are anatomical positions which are known in the art. Position C is located about 3 cm to the left of position B. Position D is located about 3 cm to the left of position C.

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Fig. 10 is a flowchart 1000 illustrating a decision matrix implemented in a processing module in an example embodiment. At step 1002, synchronous capturing of sound by the probe starts together with the triggering of the syringe driver (or pusher member). The capture time duration is set at 5 seconds. The processing time frame is set at an interval of 0.5 seconds. At step 1004, the captured sound clip is processed by a software algorithm (written in e.g. C programming language) by the processing module. At step 1006, the properties of the captured sound clip, such as frequency and power of the different sound waves of the captured sound clip are obtained. The sound properties are obtained by applying Fast Fourier Transform (FFT) to the signal. At step 1008, sound waves of particular frequencies within the critical frequency range of 80 Hz to 500 Hz are selected as qualified sound waves. A subset of frequencies and associated powers is thus obtained.

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At 1010, if there is no record of any of the captured sound waves within the critical frequency range, the processing module proceeds to step 1016 to indicate a fail and exit the program.

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If record(s) of captured sound signals within the critical frequency range is found, the processing module proceeds to step 1012. At step 1012, the total power of qualified sound waves (within the frequency range) having powers of at least 1 mW is obtained.

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In other words, for sound waves within the frequency range of 80 to 500 Hz and which have a power of at least 1mW, a summation of their powers is obtained.

At step 1014, if the summed total power of the selected sound group or subset (i.e., qualified sounds which meet the frequency range of 80 Hz to 500 Hz) is at least 12.5% of the total power in the sampling frequency range up to 10,000 Hz captured in the time duration of 5 seconds, the processing module proceeds to step 1018 to indicate a pass and exit the program. Otherwise, if the criteria at step 1014 is not met, the processing module proceeds to step 1016 to indicate a fail and exit the program. Typically, the summed total power of the selected sound group or subset comes from the initial 3 seconds of the captured sound clip.

Therefore, in an example embodiment of the present application, the processing unit is configured to obtain one or more frequencies and their respective associated powers of the captured/recorded sound signal. This may be obtained via an algorithm comprising digital signal processing techniques including a Fast Fourier Transform. A total power, P , of the one or more frequencies of sound is obtained. A total power of a subset, P_s , of the one or more frequencies of sound is also obtained. In the example embodiment, the subset may include the sum of powers of sound whose frequencies are within a frequency range of e.g. 80 Hz to 500 Hz. In addition, the subset only includes powers which are at least of a threshold power of e.g. 1 mW in magnitude. Thereafter, a percentage of the total power of the subset P_s , over the total power, P , obtained (i.e., $P_s/P \times 100\%$). A correct placement of the tube is determined if the percentage is more than or equal to a threshold percentage of e.g. 12.5%.

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Fig. 11 is a flowchart 1100 illustrating a method of determining placement of tube in an example embodiment. At step 1102, fluid is discharged into a first end of a tube with a fluid discharge module. At step 1104, sound produced at proximate the second end of the tube is captured with a sensor module. At step 1106, one or more parameters are obtained by processing the sound with a processing unit. At step 1108, placement of the tube is determined based on the one or more parameters.

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In one example embodiment, an apparatus and method of determining placement of a tube may be provided. The apparatus for determining placement of a tube is an integrated system that is able to detect the placement of an e.g. nasogastric tube (NGT) accurately in the stomach. The apparatus comprises of an electronic

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stethoscope with integrated circuitry components as a sensing module, a syringe driver as a fluid discharge module and a microprocessor unit as a processing module to analyse sound signals detected by the sensing module.

5 In operation, the electronic stethoscope is placed over the stomach region, and when air is injected into the stomach via the NGT using the syringe driver, the stethoscope captures sound produced in the vicinity of the stomach region. The captured sound is then transmitted to the microprocessor unit which analyses the sound. If the analysed sound meets certain predefined criteria, an indicator light will be
10 activated, confirming that the NGT has been correctly placed.

One advantage of an apparatus for determining placement of a tube described herein is that it provides a non-invasive apparatus for and method of determining correct placement of a nasogastric tube. The detection of sound is made from external the
15 subject body. Therefore, the apparatus and method of determining placement of a tube is safe for use on human subjects. There is no introduction of additional foreign material into the body. In contrast with the aspiration test, example embodiments of the present application do not require the introduction of any materials into the body in order to draw gastric fluid from the stomach of the subject.

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In addition, example embodiments of the present application can also advantageously prevent a subject from direct contact with electrical signals or other potentially harmful exposures e.g. X-rays, in order to determine the correct placement of the nasogastric tube.

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Example embodiments of the present application can also provide for fast and reliable confirmation of the placement of the nasogastric tube. Using Fast Fourier Transform (FFT) and digital signal filtering techniques in the processing algorithm, the entire test using the apparatus and methods described herein can be conducted in less
30 than a minute and this advantageously results in a fast and reliable method of confirming placement of the NGT tube.

Moreover, the example embodiments of the present application involve the use of a mechanical means for driving the syringe such that a constant air flow and pressure
35 is discharged into the tube.

Table 1 shows two sets of pressure readings measured during manual delivery of air from a syringe. Table 2 shows two sets of pressure readings measured during delivery of air from a syringe mounted on a fluid discharge module in an example embodiment.

5 Table 1. Pressure readings produced during manual delivery of air from syringe

Set 1 Reading		Set 2 Reading	
Attempts	Pressure/Kpa	Attempts	Pressure/Kpa
1	139.6	1	135.1
2	139.8	2	139.2
3	140.1	3	142.5
4	143.0	4	143.3
5	112.1	5	145.9
6	110.6	6	134.6
7	134.0	7	138.2
8	143.1	8	146.3
9	141.8	9	134.0
10	138.8	10	130.1
11	146.4	11	139.4
12	139.5	12	136.4
13	141.6	13	142.7
14	146.0	14	142.9
15	140.2	15	140.5
16	144.9	16	146.1
17	140.7	17	139.4
18	138.1	18	139.2
19	142.4	19	138.4
20	141.2	20	135.7
Average	138.20	Average	139.50

Table 2. Pressure readings produced during delivery of air by a fluid discharge module in an example embodiment

Set 1 Reading		Set 2 Reading	
Attempts	Pressure/Kpa	Attempts	Pressure/Kpa
1	31.52	1	33.25
2	33.22	2	33.29
3	33.71	3	33.57
4	33.88	4	34.17
5	32.25	5	33.46
6	33.44	6	33.56
7	33.55	7	33.33
8	31.98	8	32.99
9	33.24	9	32.80
10	33.80	10	32.77
11	34.09	11	32.43
12	33.88	12	33.07
13	32.29	13	31.94
14	32.82	14	32.22
15	32.74	15	33.11
16	33.64	16	32.70
17	33.12	17	31.96
18	33.31	18	32.42
19	33.62	19	32.89
20	33.29	20	32.88
Average	33.17	Average	32.94

From the results shown in Table 1 and Table 2, it is observed that the pressure produced when manually delivering air from a syringe is about 4 times higher than the pressure produced using the fluid discharge module. The pressure readings produced during manual delivery also exhibit a greater variance as compared to using the fluid discharge module.

The results of the comparison above show that a fluid discharge module is able to advantageously exert a lower and more consistent pressure when delivering fluid from the syringe. This translates to a more consistent approach to the delivery of air, and which can advantageously allow for the e.g. standard “swoosh” sound made by the fluid discharge module to be more easily detected, as the consistency in the pressure delivered can affect the sound produced.

In addition, as example embodiments of the present application rely on a decision matrix to analyse the sound produced, in order to determine the placement of the tube, any subjective factors in the determination can be removed. This is in contrast with the obsolete manual methods which are dependent on the ability of the personnel administering the tube, where the judgment and experience of the healthcare personnel is critical in the accuracy of the determination.

In the described example embodiments, the apparatus for determining placement of a tube may be a portable standalone unit and has low power consumption. This make the apparatus for determining placement of a tube a robust system with lower infrastructure cost as compared to using X-Ray imaging. Touch screen capabilities in the user interface may be provided for ease of use.

The apparatus for determining placement of a tube may be used by healthcare professionals, patients and care givers for patients who e.g. require nasogastric tube feeding. The apparatus for determining placement of a tube has several advantages and addresses or at least ameliorates the problems in existing detection methods. It may be used as an alternative method for detecting NGT placement to minimise the use of X-Rays and lowers the cost of detection for subjects.

The apparatus for determining placement of a tube and method may also result in lower cost for performing the nasogastric intubation procedure, decrease subject's cost for using NGT for feeding and reduce hospitalisation duration for patients. The apparatus for determining placement of a tube and method may also provide safe care by decreasing the occurrences of and complications arising from wrong placement of NGT. In addition, the risk of exposure to harmful radiation e.g. X-ray radiation, may also be decreased.

The ease of use of the apparatus and methods described herein can also allow increased time-efficiency in teaching caregivers in the care for NGT feeding procedure. Further, errors arising from e.g. incorrect placement of nasogastric tube can reduced, which is beneficial to both the caregiver and patient. The reduced risk of error in e.g. tube placement may also decrease the potential exposure of healthcare personnel and organisations to legal proceedings or complaints.

Different example embodiments can be implemented in the context of data structure, program modules, program and computer instructions executed in a computer implemented environment. A general purpose computing environment is briefly disclosed herein. One or more example embodiments may be embodied in one or more computer systems, such as is schematically illustrated in Figure 12. For example, the processing module as disclosed herein may be implemented in a general purpose computing environment.

One or more example embodiments may be implemented as software, such as a computer program being executed within a computer system 1200, and instructing the computer system 1200 to conduct a method of an example embodiment.

The computer system 1200 comprises a computer unit 1202, input modules such as a keyboard 1204 and a pointing device 1206 and a plurality of output devices such as a display 1208, and printer 1210. A user can interact with the computer unit 1202 using the above devices. The pointing device can be implemented with a mouse, track ball, pen device or any similar device. One or more other input devices (not shown) such as a joystick, game pad, satellite dish, scanner, touch sensitive screen or the like can also be connected to the computer unit 1202. The display 1208 may include a cathode ray tube (CRT), liquid crystal display (LCD), field emission display (FED), plasma display or any other device that produces an image that is viewable by the user.

The computer unit 1202 can be connected to a computer network 1212 via a suitable transceiver device 1214, to enable access to e.g. the Internet or other network systems such as Local Area Network (LAN) or Wide Area Network (WAN) or a personal network. The network 1212 can comprise a server, a router, a network personal computer, a peer device or other common network node, a wireless telephone or wireless personal digital assistant. Networking environments may be found in offices, enterprise-wide computer networks and home computer systems etc. The transceiver device 1214 can be a modem/router unit located within or external to the computer unit 1202, and may be any type of modem/router such as a cable modem or a satellite modem.

It will be appreciated that network connections shown are exemplary and other ways of establishing a communications link between computers can be used. The existence of any of various protocols, such as TCP/IP, Frame Relay, Ethernet, FTP, HTTP and the like, is presumed, and the computer unit 1202 can be operated in a client-server configuration to

permit a user to retrieve web pages from a web-based server. Furthermore, any of various web browsers can be used to display and manipulate data on web pages.

The computer unit 1202 in the example comprises a processor 1218, a Random Access Memory (RAM) 1220 and a Read Only Memory (ROM) 1222. The ROM 1222 can be a system memory storing basic input/ output system (BIOS) information. The RAM 1220 can store one or more program modules such as operating systems, application programs and program data.

The computer unit 1202 further comprises a number of Input/Output (I/O) interface units, for example I/O interface unit 1224 to the display 1208, and I/O interface unit 1226 to the keyboard 1204. The components of the computer unit 1202 typically communicate and interface/couple connectedly via an interconnected system bus 1228 and in a manner known to the person skilled in the relevant art. The bus 1228 can be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures.

It will be appreciated that other devices can also be connected to the system bus 1228. For example, a universal serial bus (USB) interface can be used for coupling a video or digital camera to the system bus 1228. An IEEE 1394 interface may be used to couple additional devices to the computer unit 1202. Other manufacturer interfaces are also possible such as FireWire developed by Apple Computer and i.Link developed by Sony. Coupling of devices to the system bus 1228 can also be via a parallel port, a game port, a PCI board or any other interface used to couple an input device to a computer. It will also be appreciated that, while the components are not shown in the figure, sound/audio can be recorded and reproduced with a microphone and a speaker. A sound card may be used to couple a microphone and a speaker to the system bus 1228. It will be appreciated that several peripheral devices can be coupled to the system bus 1228 via alternative interfaces simultaneously.

An application program can be supplied to the user of the computer system 1200 being encoded/stored on a data storage medium such as a CD-ROM or flash memory carrier. The application program can be read using a corresponding data storage medium drive of a data storage device 1230. The data storage medium is not limited to being portable and can include instances of being embedded in the computer unit 1202. The data storage device 1230 can comprise a hard disk interface unit and/or a removable memory interface unit (both

not shown in detail) respectively coupling a hard disk drive and/or a removable memory drive to the system bus 1228. This can enable reading/writing of data. Examples of removable memory drives include magnetic disk drives and optical disk drives. The drives and their associated computer-readable media, such as a floppy disk provide nonvolatile storage of computer readable instructions, data structures, program modules and other data for the computer unit 1202. It will be appreciated that the computer unit 1202 may include several of such drives. Furthermore, the computer unit 1202 may include drives for interfacing with other types of computer readable media.

The application program is read and controlled in its execution by the processor 1218. Intermediate storage of program data may be accomplished using RAM 1220. The method(s) of the example embodiments can be implemented as computer readable instructions, computer executable components, or software modules. One or more software modules may alternatively be used. These can include an executable program, a data link library, a configuration file, a database, a graphical image, a binary data file, a text data file, an object file, a source code file, or the like. When one or more computer processors execute one or more of the software modules, the software modules interact to cause one or more computer systems to perform according to the teachings herein.

In an example embodiment, a central processing unit ARM Cortex M3 (LPC1788) processor may be provided within the housing. The algorithm for the decision matrix and algorithm may be created with the "C" programming language for implementation in the processing unit.

The operation of the computer unit 1202 can be controlled by a variety of different program modules. Examples of program modules are routines, programs, objects, components, data structures, libraries, etc. that perform particular tasks or implement particular abstract data types. The example embodiments may also be practiced with other computer system configurations, including handheld devices, embedded systems in a multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, personal digital assistants, mobile telephones and the like. Furthermore, the example embodiments may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a wireless or wired communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

Different example embodiments can be implemented in the context of data structure, program modules, program and computer instructions executed in a communication device. An exemplary communication device is briefly disclosed herein. One or more example
5 embodiments may be embodied in one or more communication devices e.g. 1300, such as is schematically illustrated in Figure 13. For example, the processing unit described herein may be implanted in a communication device.

One or more example embodiments may be implemented as software, such as a
10 computer program being executed within a communication device 1300, and instructing the communication device 1300 to conduct a method of an example embodiment.

The communication device 1300 comprises a processor module 1302, an input module such as a touchscreen interface or a keypad 1304 and an output module such as a
15 display 1306 on a touchscreen.

The processor module 1302 is coupled to a first communication unit 1308 for communication with a cellular network 1310. The first communication unit 1308 can include, but is not limited to, a subscriber identity module (SIM) card loading bay. The cellular
20 network 1310 can, for example, be a 3G or 4G network.

The processor module 1302 is further coupled to a second communication unit 1312 for connection to a network 1314. For example, the second communication unit 1312 can enable access to e.g. the Internet or other network systems such as Local Area Network
25 (LAN) or Wide Area Network (WAN) or a personal network. The network 1314 can comprise a server, a router, a network personal computer, a peer device or other common network node, a wireless telephone or wireless personal digital assistant. Networking environments may be found in offices, enterprise-wide computer networks and home computer systems etc. The second communication unit 1312 can include, but is not limited to, a wireless
30 network card or an ethernet network cable port. The second communication unit 1312 can also be a modem/router unit and may be any type of modem/router such as a cable-type modem or a satellite-type modem.

It will be appreciated that network connections shown are exemplary and other ways
35 of establishing a communications link between computers can be used. The existence of any of various protocols, such as TCP/IP, Frame Relay, Ethernet, FTP, HTTP and the like, is

presumed, and the communication device 1300 can be operated in a client-server configuration to permit a user to retrieve web pages from a web-based server. Furthermore, any of various web browsers can be used to display and manipulate data on web pages.

5 The processor module 1302 in the example includes a processor 1316, a Random Access Memory (RAM) 1318 and a Read Only Memory (ROM) 1320. The ROM 1320 can be a system memory storing basic input/ output system (BIOS) information. The RAM 1318 can store one or more program modules such as operating systems, application programs and program data.

10 The processor module 1302 also includes a number of Input/Output (I/O) interfaces, for example I/O interface 1322 to the display 1306, and I/O interface 1324 to the keypad 1304.

15 The components of the processor module 1302 typically communicate and interface/couple connectedly via an interconnected bus 1326 and in a manner known to the person skilled in the relevant art. The bus 1326 can be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures.

20 It will be appreciated that other devices can also be connected to the system bus 1326. For example, a universal serial bus (USB) interface can be used for coupling an accessory of the communication device, such as a card reader, to the system bus 1326.

25 The application program is typically supplied to the user of the communication device 1300 encoded on a data storage medium such as a flash memory module or memory card/stick and read utilising a corresponding memory reader-writer of a data storage device 1328. The data storage medium is not limited to being portable and can include instances of being embedded in the communication device 1300.

30 The application program is read and controlled in its execution by the processor 1316. Intermediate storage of program data may be accomplished using RAM 1318. The method(s) of the example embodiments can be implemented as computer readable instructions, computer executable components, or software modules. One or more software modules may
35 alternatively be used. These can include an executable program, a data link library, a configuration file, a database, a graphical image, a binary data file, a text data file, an object

file, a source code file, or the like. When one or more processor modules execute one or more of the software modules, the software modules interact to cause one or more processor modules to perform according to the teachings herein.

5 The operation of the communication device 1300 can be controlled by a variety of different program modules. Examples of program modules are routines, programs, objects, components, data structures, libraries, etc. that perform particular tasks or implement particular abstract data types.

10 The example embodiments may also be practiced with other computer system configurations, including handheld devices, multiprocessor systems/servers, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, personal digital assistants, mobile telephones and the like. Furthermore, the example embodiments may also be practiced in distributed computing
15 environments where tasks are performed by remote processing devices that are linked through a wireless or wired communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

 The description herein may be, in certain portions, explicitly or implicitly described as
20 algorithms and/or functional operations that operate on data within a computer memory or an electronic circuit. These algorithmic descriptions and/or functional operations are usually used by those skilled in the information/data processing arts for efficient description. An algorithm is generally relating to a self-consistent sequence of steps leading to a desired result. The algorithmic steps can include physical manipulations of physical quantities, such
25 as electrical, magnetic or optical signals capable of being stored, transmitted, transferred, combined, compared, and otherwise manipulated.

 Further, unless specifically stated otherwise, and would ordinarily be apparent from the following, a person skilled in the art will appreciate that throughout the present
30 specification, discussions utilizing terms such as “scanning”, “calculating”, “determining”, “replacing”, “generating”, “initializing”, “outputting”, “recording”, “obtaining”, “capturing”, “processing” and the like, refer to action and processes of an instructing processor/computer system, or similar electronic circuit/device/component, that manipulates/processes and transforms data represented as physical quantities within the described system into other
35 data similarly represented as physical quantities within the system or other information storage, transmission or display devices etc.

The description also discloses relevant device/apparatus for performing the steps of the described methods. Such apparatus may be specifically constructed for the purposes of the methods, or may comprise a general purpose computer/processor or other device selectively activated or reconfigured by a computer program stored in a storage member. The algorithms and displays described herein are not inherently related to any particular computer or other apparatus. It is understood that general purpose devices/machines may be used in accordance with the teachings herein. Alternatively, the construction of a specialized device/apparatus to perform the method steps may be desired.

In addition, it is submitted that the description also implicitly covers a computer program, in that it would be clear that the steps of the methods described herein may be put into effect by computer code. It will be appreciated that a large variety of programming languages and coding can be used to implement the teachings of the description herein. Moreover, the computer program if applicable is not limited to any particular control flow and can use different control flows without departing from the scope of the invention.

Furthermore, one or more of the steps of the computer program if applicable may be performed in parallel and/or sequentially. Such a computer program if applicable may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a suitable reader/general purpose computer. In such instances, the computer readable storage medium is non-transitory. Such storage medium also covers all computer-readable media e.g. medium that stores data only for short periods of time and/or only in the presence of power, such as register memory, processor cache and Random Access Memory (RAM) and the like. The computer readable medium may even include a wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in bluetooth technology. The computer program when loaded and executed on a suitable reader effectively results in an apparatus that can implement the steps of the described methods.

The example embodiments may also be implemented as hardware modules. A module is a functional hardware unit designed for use with other components or modules. For example, a module may be implemented using digital or discrete electronic components, or it can form a portion of an entire electronic circuit such as an Application Specific

Integrated Circuit (ASIC). A person skilled in the art will understand that the example embodiments can also be implemented as a combination of hardware and software modules.

Additionally, when describing some embodiments, the disclosure may have disclosed a method and/or process as a particular sequence of steps. However, unless otherwise required, it will be appreciated the method or process should not be limited to the particular sequence of steps disclosed. Other sequences of steps may be possible. The particular order of the steps disclosed herein should not be construed as undue limitations. Unless otherwise required, a method and/or process disclosed herein should not be limited to the steps being carried out in the order written. The sequence of steps may be varied and still remain within the scope of the disclosure.

Further, in the description herein, the word "substantially" whenever used is understood to include, but not restricted to, "entirely" or "completely" and the like. In addition, terms such as "comprising", "comprise", and the like whenever used, are intended to be non-restricting descriptive language in that they broadly include elements/components recited after such terms, in addition to other components not explicitly recited. Further, terms such as "about", "approximately" and the like whenever used, typically means a reasonable variation, for example a variation of +/- 5% of the disclosed value, or a variance of 4% of the disclosed value, or a variance of 3% of the disclosed value, a variance of 2% of the disclosed value or a variance of 1% of the disclosed value.

Furthermore, in the description herein, certain values may be disclosed in a range. The values showing the end points of a range are intended to illustrate a preferred range. Whenever a range has been described, it is intended that the range covers and teaches all possible sub-ranges as well as individual numerical values within that range. That is, the end points of a range should not be interpreted as inflexible limitations. For example, a description of a range of 1% to 5% is intended to have specifically disclosed sub-ranges 1% to 2%, 1% to 3%, 1% to 4%, 2% to 3% etc., as well as individually, values within that range such as 1%, 2%, 3%, 4% and 5%. The intention of the above specific disclosure is applicable to any depth/breadth of a range.

The terms "coupled" or "connected" as used in this description are intended to cover both directly connected or connected through one or more intermediate means, unless otherwise stated.

In the described example embodiments, the sensing module has been described to transmit sound signals via a cable to the user interface module. However, the sensing module is not limited as such, and may transmit sound signals wirelessly. The sensing module may also be a recording device, provide noise reduction, signal enhancement and send the sound signals wirelessly to the processing module.

In the described example embodiments, the processing module has been described to begin recording signals simultaneously with the triggering of the fluid discharge module to begin discharging fluid. That is, synchronous measurement or precision trigger measurement. However, it is appreciated that the processing module may be configured to include a delay between the starting time of the processing module to record signals and the starting time of the fluid discharge module to discharge fluid.

In the described example embodiment, Fast Fourier Transform (FFT) has been described to process the recorded sound signals. FFT is selected because it is a fast and simple technique to obtain the power and frequency of an audio signal. However, it is not limited as such, and other digital signal processing methods of obtaining frequencies and power of the audio signal may also be implemented.

In example embodiments, the flow rate produced by the fluid discharge module may be 5 ml/s, or 10 ml/s, or 15 ml/s, or 20 ml/s, or 25 ml/s, or 30 ml/s, or 35 ml/s, or 40 ml/s, or 45 ml/s, 50 ml/s. Preferably, the flow rate produced by the fluid discharge module is 20 ml/s.

In example embodiments, the pressure produced by the fluid discharge module may be about 20 kPa, or about 25 kPa, or about 30 kPa, or about 35 kPa, or about 40 kPa, or about 45 kPa, or about 50 kPa. Preferably, the fluid discharge module produces pressure of 31.5 kPa to about 34.2 kPa per discharge.

In example embodiments, the time frame or duration for delivering, dispensing or discharging fluid or air may be 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s, or 5.0 s. Preferably, the time frame or duration for delivering, dispensing or discharging fluid or air is 0.5 s.

In example embodiments, the time frame duration for capturing or recording sound signals may be 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s,

or 5.0 s. Preferably, the time frame or duration for capturing or recording sound signals is between 3.0s to 5.0s.

5 In example embodiments, the processing time frame for analysing sound signal may be 0.1 s, or 0.2 s, or 0.3 s, or 0.4 s, or 0.5 s, or 0.6 s, or 0.7 s, or 0.8 s, or 0.9 s, or 1.0 s.

10 In example embodiments, the average power of the sound signal may be at least 1 mW, or at least 2 mW, or at least 3 mW, or at least 4 mW, or at least 5 mW, or at least 6 mW, or at least 7 mW, or at least 8 mW, or at least 9 mW, or at least 10 mW.

15 In example embodiments, the critical frequency range may be from about 80 Hz to about 1000 Hz, or from about 100 Hz to about 900 Hz, or from about 200 Hz to about 800 Hz, or from about 300 Hz to about 700 Hz, or from about 400 Hz to about 600 Hz, or from about 500 Hz to about 600 Hz. Preferably, the critical frequency range is from 80 Hz to 500Hz.

20 It will be appreciated by a person skilled in the art that other variations and/or modifications may be made to the specific embodiments without departing from the scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. An apparatus for determining a placement of a tube, the apparatus comprising

5 a fluid discharge module for discharging fluid into a first end of the tube;
a sensor module for capturing sound produced at an approximate vicinity of the second end of the tube; and

a processing unit for processing the sound to obtain one or more parameters; said one or more parameters for determining the placement of the tube.

10 2. The apparatus as claimed in claim 1, wherein the fluid discharge module is configured to discharge fluid with a constant flow rate for a first duration of time.

15 3. The apparatus as claimed in claim 2, wherein the flow rate is any one of 5 ml/s, or 10 ml/s, or 15 ml/s, or 20 ml/s, or 25 ml/s, or 30 ml/s, or 35 ml/s, or 40 ml/s, or 45 ml/s, or 50 ml/s.

4. The apparatus as claimed in claim 2 or 3, wherein the first duration of time is any one of 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0s.

20 5. The apparatus as claimed in any one of claims 1 to 4, wherein the fluid discharge module is configured to push air into the first end of the tube.

25 6. The apparatus as claimed in claim 5, wherein the fluid discharge module is configured to push a plunger of a fluid containing vessel to discharge air out from the fluid containing vessel through a nozzle of the fluid containing vessel, said nozzle coupled to the first end of the tube.

30 7. The apparatus as claimed in claim 6, wherein the fluid discharge module further comprises a holder assembly for maintaining the fluid containing vessel in a fixed position.

35 8. The apparatus as claimed in claim 6 or 7, wherein the fluid discharge module further comprises a pusher assembly for providing a force on the plunger end of the fluid containing vessel.

9. The apparatus as claimed in claim 8, wherein the pusher assembly further comprises a pusher aligned along a same longitudinal axis as the plunger.

10. The apparatus as claimed in claim 9, wherein the pusher is configured to
5 apply on the plunger end of the fluid containing vessel, an average pressure from about 31.5 kPa to about 34.2 kPa.

11. The apparatus as claimed in any one of claims 8 to 10, wherein the
pusher assembly further comprises
10 an elastic element capable of being loaded;
wherein releasing the elastic element from a loaded state provides the force on the plunger end of the fluid containing vessel.

12. The apparatus as claimed in any one of claim 9 to 11, wherein the fluid
15 discharge module further comprises
a signalling means for detecting the movement or position of the pusher and for signalling the processing unit based on the detected movement or position.

13. The apparatus as claimed in claim 12, wherein the pusher further
20 comprises a magnet such that the magnet is capable of moving in tandem with the pusher; and
the signalling means comprising a magnetic switch for interacting with the magnet.

14. The apparatus as claimed in claim 12 or 13, wherein the signalling means
25 transmits a signal to the processing unit to trigger the capturing of sound based on the detected movement or position of the magnet.

15. The apparatus as claim in any one of claims 1 to 14, wherein the sensor
30 module further comprises an audio receiver for receiving sound.

16. The apparatus as claimed in claim 15, wherein the sensor module comprises a stethoscope for receiving the sound.

17. The apparatus as claimed in any one of claims 1 to 16, wherein the
35 sensor module is capable of transmitting the captured sound to the processing unit.

18. The apparatus as claimed in any one of claims 1 to 17, wherein the fluid discharge module and sensor discharge module are configured to synchronise the discharge of fluid into the first end of the tube with the capturing of sound produced at the approximate vicinity of the second end of the tube.

19. The apparatus as claimed in any one of claims 1 to 18, wherein the processing module is further configured to record the sound.

20. The apparatus as claimed in claim 19, wherein the processing module is configured to record the sound over a second duration of any one of 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s, or 5.0

21. The apparatus as claimed in any one of the preceding claims, wherein the processing unit is configured to obtain one or more frequencies of the sound and associated powers corresponding to the one or frequencies of the sound.

22. The apparatus as claimed in claim 21, wherein the processing unit is further configured to apply a digital signal processing technique to obtain the one or more frequencies and associated powers corresponding to the one or more frequencies of the sound.

23. The apparatus as claimed in claim 22, wherein the processing unit is configured to apply a Fast Fourier Transform to the sound.

24. The apparatus as claimed in any one of claims 21 to 23, wherein the processing unit is further configured to obtain a total power of the one or more frequencies of the sound.

25. The apparatus as claimed in any one of claims 21 to 24, wherein the processing unit is further configured to obtain a total power of a subset of the one or more frequencies of the sound.

26. The apparatus as claimed in claim 25, wherein the subset of the one or more frequencies of the sound comprises frequencies from a critical frequency range.

27. The apparatus as claimed in claim 26, wherein the critical frequency range is from 80 Hz to 500 Hz.

28. The apparatus as claimed in any one of claims 25 to 27, wherein the processing unit configured to obtain the total power of the subset comprises obtaining a sum of powers in the subset which are at least of a threshold power.

29. The apparatus as claimed in claim 28, wherein the threshold power is 1 mW.

30. The apparatus as claimed in any one of claims 25 to 29, wherein the processing unit is further configured to obtain a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one or more frequencies of the sound.

31. The apparatus as claimed in claim 30, wherein the processing unit determines a correct placement of the tube if the percentage is more than or equal to a threshold percentage.

32. The apparatus as claimed in claim 31, wherein the threshold percentage is 12.5%.

33. The apparatus as claimed in any one of claims 1 to 32, further comprising output means for providing a visual and/ or audio output signal to indicate correct or incorrect placement of the tube.

34. A method of determining a placement of a tube, the method comprising discharging fluid into a first end of the tube with a fluid discharge module; capturing sound produced at proximate the second end of the tube with a sensor module; processing the sound to obtain one or more parameters with a processing unit; and determining the placement of the tube based on the one or more parameters.

35. The method as claimed in claim 34, discharging fluid further comprises discharging fluid with a constant flow rate for a first duration of time.

36. The method as claimed in claim 35, wherein the flow rate is any one of 5 ml/s, or 10 ml/s, or 15 ml/s, or 20 ml/s, or 25 ml/s, or 30 ml/s, or 35 ml/s, or 40 ml/s, or 45 ml/s, or 50 ml/s.

5

37. The method as claimed in claim 35 or 36, wherein the first duration of time is any one of 0.5 s, or 1.0 s, or 1.5 s, or 2.0 s, or 2.5 s, or 3.0s.

38. The method as claimed in any one of claims 34 to 37, wherein
10 discharging fluid further comprises pushing air into the first end of the tube by the fluid discharge module.

39. The method as claimed in claim 38, wherein pushing air into the first end
of the tube further comprises pushing a plunger of a fluid containing vessel to discharge
15 air out from the fluid containing vessel through a nozzle of the fluid containing vessel,
said nozzle coupled to the first end of the tube.

40. The method as claimed in claim 39, further comprising maintaining the
fluid containing vessel in a fixed position using a holder assembly.

20

41. The method as claimed in claim 39 or 40, wherein pushing the plunger
comprises providing a force on the plunger end of the fluid containing vessel with a
pusher assembly.

42. The method as claimed in claim 41, wherein a pusher of the pusher
25 assembly is aligned along a same longitudinal axis as the plunger.

43. The method as claimed in claim 41 or 42, wherein pushing the plunger
comprises applying an average pressure from about 31.5 kPa to about 34.2 kPa on the
30 plunger end of the fluid containing vessel.

44. The method as claimed in any one of claims 41 to 43, wherein pushing
the plunger comprises
loading an elastic element of the pusher assembly; and
35 releasing the elastic element from the loading;
wherein releasing the elastic element provides the force on the plunger end.

45. The method as claimed in any one of claims 42 to 44, further comprising detecting the movement or position of the pusher; and signalling the processing unit based on the detected movement or position.

5

46. The method as claimed in claim 45, wherein detecting the movement or position of the pusher comprises providing a magnet to move in tandem with the pusher; and providing a magnetic switch for interacting with the magnet.

10

47. The method as claimed in claim 46, wherein signalling the processing unit based on the detected movement or position comprises transmitting a signal to the processing unit to trigger the capturing of sound based on the detected movement or position of the magnet.

15

48. The method as claimed in any one of claims 34 to 47, wherein capturing sound further comprises receiving sound with an audio receiver.

49. The method as claimed in claim 48, wherein receiving sound further comprises receiving the sound with a stethoscope.

20

50. The method as claimed in any one of claims 34 to 49, further comprising transmitting the captured sound to the processing unit.

51. The method as claimed in any one of claims 34 to 50, wherein discharging fluid into a first end of the tube with a fluid discharge module and capturing sound produced at an approximate vicinity of the second end of the tube with a sensor is synchronised.

25

52. The method as claimed in any one of claims 34 to 51, further comprising recording the sound with the processing unit.

30

53. The method as claimed in claim 52, wherein recording the sound comprises recording the sound over a second duration of any one of 3.0 s, or 3.5 s, or 4.0 s, or 4.5 s, or 5.0 s.

35

54. The method as claimed in any one of claims 34 to 53, wherein processing the sound to obtain one or more parameters comprises obtaining one or more frequencies of the sound and associated powers corresponding to the one or more frequencies of the sound.

5

55. The method as claimed in claim 54, wherein obtaining the one or more frequencies and associated powers corresponding to the one or more frequencies of the sound comprises applying a digital signal processing technique.

10

56. The method as claimed in claim 55, wherein the digital signal processing technique comprises Fast Fourier Transform.

57. The method as claimed in any one of claims 54 to 56, further comprising obtaining a total power of the one or more frequencies of the sound.

15

58. The method as claimed in any one of claims 54 to 57, further comprising obtaining a total power of a subset of the one or more frequencies of the sound.

59. The method as claimed in claim 58, wherein the subset of the one or more frequencies of the sound has frequencies from a critical frequency range.

20

60. The method as claimed in claim 59, wherein the critical frequency range is from 80 Hz to 500 Hz.

61. The method as claimed in any one of claims 58 to 60, wherein obtaining a total power of the subset comprises obtaining a sum of associated powers in the subset which are at least a threshold power.

25

62. The method as claimed claim 61, wherein the threshold power is 1 mW.

30

63. The method as claimed in any one of claims 58 to 62, further comprising obtaining a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one or more frequencies of the sound.

64. The method as claimed in claim 63, wherein determining a correct placement of the tube comprises obtaining a percentage value of more than or equal to a threshold percentage.

5 65. The method as claimed in claim 64, wherein the threshold percentage is 12.5%.

66. The method as claimed in any one of claims 34 to 65, further comprising providing a visual and/ or audio output signal to indicate correct or incorrect placement
10 of the tube.

67. A method of determining a placement of a tube, the method comprising discharging fluid into a first end of the tube with a fluid discharge module; capturing sound produced at proximate a second end of the tube with a sensor
15 module;

processing the sound with a processing unit to obtain one or more frequencies of the sound and associated powers corresponding to the one or frequencies of the sound; and

determining the placement of the tube based on a total power of a subset of the
20 one or more frequencies of the sound over a total power of the one or more frequencies of the sound.

68. The method as claimed in claim 67, wherein the subset of the one or more frequencies of the sound has frequencies from a critical frequency range.

69. The method as claimed in claim 67 or 68, wherein the total power of a subset of the one or more frequencies of the sound comprises a sum of associated powers in the subset which are at least a threshold power.

70. The method as claimed in any one of claims 67 to 69, further comprising obtaining a percentage of the total power of the subset of the one or more frequencies of the sound over the total power of the one or more frequencies of the sound.

71. The method as claimed in claim 70, wherein determining a correct
35 placement of the tube comprises obtaining a percentage value of more than or equal to a threshold percentage.

72. A non-transitory computer readable storage medium having stored thereon instructions for instructing a processing module of an apparatus to execute a method of determining placement of a tube, the method comprising,

5 discharging fluid into a first end of the tube with a fluid discharge module;
 capturing sound produced at proximate the second end of the tube with a sensor module;

 processing the sound to obtain one or more parameters with a processing unit;
and

10 determining the placement of the tube based on the one or more parameters.

73. A non-transitory computer readable storage medium having stored thereon instructions for instructing a processing module of an apparatus to execute a method of determining placement of a tube, the method comprising,

15 discharging fluid into a first end of the tube with a fluid discharge module;
 capturing sound produced at proximate a second end of the tube with a sensor module;

 processing the sound with a processing unit to obtain one or more frequencies of the sound and associated powers corresponding to the one or frequencies of the sound;

20 and

 determining the placement of the tube based on a total power of a subset of the one or more frequencies of the sound over a total power of the one or more frequencies of the sound.