SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION

Abstract

Various systems and methods providing recommendations based on analysis of surgical procedure variables are disclosed. A computer system, such as a surgical hub, can be configured to be communicably coupled to a surgical device. The computer system can be programmed to determine contextual data related to the surgical procedure being performed based at least in part of perioperative data received from the surgical device paired with the computer system. Further, the computer system can determine a procedural variable associated with the determined surgical context and then compare the procedural variable to a baseline. Depending upon the outcome of the comparison, the computer system can provide intraoperative or postoperative recommendations to the surgical staff.

Inventors: **Shelton, IV; Frederick E. (Hillsboro, OH), Harris; Jason L. (Lebanon, OH), Aronhalt; Taylor W. (Loveland, OH)**

Applicant: **Cilag GmbH International** (Zug, CH)

Related U.S. Application Data

parent US continuation 17210839 20210324 parent-grant-document US 12256995 child US 19070036
parent US continuation 16182290 20181106 parent-grant-document US 11969216 child US 17210839
us-provisional-application US 62729191 20180910

us-provisional-application US 62692747 20180630
us-provisional-application US 62692748 20180630
us-provisional-application US 62692768 20180630
us-provisional-application US 62659900 20180419
us-provisional-application US 62650898 20180330
us-provisional-application US 62650887 20180330
us-provisional-application US 62650882 20180330
us-provisional-application US 62650877 20180330
us-provisional-application US 62640417 20180308
us-provisional-application US 62640415 20180308
us-provisional-application US 62611341 20171228
us-provisional-application US 62611340 20171228
us-provisional-application US 62611339 20171228

Publication Classification

Int. Cl.: **A61B34/10** (20160101); **A61B17/00** (20060101); **A61B17/072** (20060101); **A61B17/32** (20060101); **A61B18/00** (20060101); **A61B18/14** (20060101); **A61B34/00** (20160101); **A61B34/20** (20160101); **A61B34/30** (20160101); **A61B90/98** (20160101); **G16H20/40** (20180101); **G16H40/63** (20180101)

U.S. Cl.:

CPC   **A61B34/10** (20160201); **A61B17/07207** (20130101); **A61B34/30** (20160201); **A61B90/98** (20160201); **G16H20/40** (20180101); **G16H40/63** (20180101); A61B2017/00022 (20130101); A61B2017/00057 (20130101); A61B2017/00123 (20130101); A61B2017/00221 (20130101); A61B2017/00398 (20130101); A61B17/320068 (20130101); A61B2018/0063 (20130101); A61B18/14 (20130101); A61B2034/2065 (20160201); A61B2034/252 (20160201); A61B2034/256 (20160201); A61B2218/002 (20130101); A61B2218/006 (20130101); A61B2218/008 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present application is a continuation patent application claiming priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 17/210,839, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL, filed Mar. 24, 2021, now U.S. Patent Publication No. 2021/0205020, which claims priority under 35 U.S.C. § 120 to U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/729,191, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed on Sep. 10, 2018, the disclosure of each of which is herein incorporated by reference in its entirety. [0002] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING

DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/692,747, titled SMART ACTIVATION OF AN ENERGY DEVICE BY ANOTHER DEVICE, filed on Jun. 30, 2018, to U.S. Provisional Patent Application Ser. No. 62/692,748, titled SMART ENERGY ARCHITECTURE, filed on Jun. 30, 2018, and to U.S. Provisional Patent Application Ser. No. 62/692,768, titled SMART ENERGY DEVICES, filed on Jun. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety.

[0003] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed on Apr. 19, 2018, the disclosure of each of which is herein incorporated by reference in its entirety. [0004] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/650,898 filed on Mar. 30, 2018, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS, to U.S. Provisional Patent Application Ser. No. 62/650,887, titled SURGICAL SYSTEMS WITH OPTIMIZED SENSING CAPABILITIES, filed Mar. 30, 2018, to U.S. Provisional Patent Application Ser. No. 62/650,882, titled SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM, filed Mar. 30, 2018, and to U.S. Provisional Patent Application Ser. No. 62/650,877, titled SURGICAL SMOKE EVACUATION SENSING AND CONTROLS, filed Mar. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety. [0005] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which also claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/640,417, titled TEMPERATURE CONTROL IN ULTRASONIC DEVICE AND CONTROL SYSTEM THEREFOR, filed Mar. 8, 2018, and to U.S. Provisional Patent Application Ser. No. 62/640,415, titled ESTIMATING STATE OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR, filed Mar. 8, 2018, the disclosure of each of which is herein incorporated by reference in its entirety. [0006] U.S. patent application Ser. No. 16/182,290, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION, filed Nov. 6, 2018, now U.S. Pat. No. 11,969,216, which also claims the benefit of priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, to U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS, filed Dec. 28, 2017, and to U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of each of which is herein incorporated by reference in its entirety.

BACKGROUND

[0007] The present disclosure relates to various surgical systems. Surgical procedures are typically performed in surgical operating theaters or rooms in a healthcare facility such as, for example, a hospital. A sterile field is typically created around the patient. The sterile field may include the scrubbed team members, who are properly attired, and all furniture and fixtures in the area. Various

surgical devices and systems are utilized in performance of a surgical procedure.

SUMMARY

[0008] In one general aspect, a computer system configured to be communicably coupled to a surgical device. The computer system comprises a processor and a memory coupled to the processor. The memory stores instructions that, when executed by the processor, cause the computer system to: receive perioperative data from the surgical device; determine a surgical context based at least in part on the perioperative data; determine a procedural variable associated with the surgical context; compare the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and provide a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

[0009] In another general aspect, a computer-implemented method for providing recommendations associated with a surgical procedure, the method comprising: receiving, by a computer system, perioperative data from a surgical device; determining, by the computer system, a surgical context based at least in part on the perioperative data; determining, by the computer system, a procedural variable associated with the surgical context; comparing, by the computer system, the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and providing, by the computer system, a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

[0010] In yet another general aspect, a computer system configured to be communicably coupled to a surgical device and a video camera. The computer system comprises a processor and a memory coupled to the processor. The memory stores instructions that, when executed by the processor, cause the computer system to: record a surgical procedure via the video camera; receive perioperative data from the surgical device; determine a surgical context based at least in part on the perioperative data; determine a procedural variable associated with the surgical context; compare the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and replay a recording of the surgical procedure, the recording including a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

Description

FIGURES

[0011] The various aspects described herein, both as to organization and methods of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings as follows.

[0012] FIG. **1** is a block diagram of a computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure.

[0013] FIG. **2** is a surgical system being used to perform a surgical procedure in an operating room, in accordance with at least one aspect of the present disclosure.

[0014] FIG. **3** is a surgical hub paired with a visualization system, a robotic system, and an intelligent instrument, in accordance with at least one aspect of the present disclosure.

[0015] FIG. **4** is a partial perspective view of a surgical hub enclosure, and of a combo generator module slidably receivable in a drawer of the surgical hub enclosure, in accordance with at least one aspect of the present disclosure.

[0016] FIG. **5** is a perspective view of a combo generator module with bipolar, ultrasonic, and monopolar contacts and a smoke evacuation component, in accordance with at least one aspect of the present disclosure.

[0017] FIG. **6** illustrates individual power bus attachments for a plurality of lateral docking ports of a lateral modular housing configured to receive a plurality of modules, in accordance with at least

one aspect of the present disclosure.

[0018] FIG. **7** illustrates a vertical modular housing configured to receive a plurality of modules, in accordance with at least one aspect of the present disclosure.

[0019] FIG. **8** illustrates a surgical data network comprising a modular communication hub configured to connect modular devices located in one or more operating theaters of a healthcare facility, or any room in a healthcare facility specially equipped for surgical operations, to the cloud, in accordance with at least one aspect of the present disclosure.

[0020] FIG. **9** illustrates a computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure.

[0021] FIG. **10** illustrates a surgical hub comprising a plurality of modules coupled to the modular control tower, in accordance with at least one aspect of the present disclosure.

[0022] FIG. **11** illustrates one aspect of a Universal Serial Bus (USB) network hub device, in accordance with at least one aspect of the present disclosure.

[0023] FIG. **12** is a block diagram of a cloud computing system comprising a plurality of smart surgical instruments coupled to surgical hubs that may connect to the cloud component of the cloud computing system, in accordance with at least one aspect of the present disclosure.

[0024] FIG. **13** is a functional module architecture of a cloud computing system, in accordance with at least one aspect of the present disclosure.

[0025] FIG. **14** illustrates a diagram of a situationally aware surgical system, in accordance with at least one aspect of the present disclosure.

[0026] FIG. **15** is a timeline depicting situational awareness of a surgical hub, in accordance with at least one aspect of the present disclosure.

[0027] FIG. **16** is a logic flow diagram for a process of providing surgical recommendations, in accordance with at least one aspect of the present disclosure.

[0028] FIG. **17** is a series of graphical displays of a video feed of a surgeon dissecting a vessel to present for transection, in accordance with at least one aspect of the present disclosure.

[0029] FIG. **18** is a graphical user interface for replaying a surgical procedure, in accordance with at least one aspect of the present disclosure.

[0030] FIG. **19** is a graphical user interface for viewing a recommendation associated with a surgical procedure and its underlying historical data, in accordance with at least one aspect of the present disclosure.

DESCRIPTION

[0031] Applicant of the present application owns the following U.S. patent applications, filed on Nov. 6, 2018, the disclosure of each of which is herein incorporated by reference in its entirety:

[0032] U.S. patent application Ser. No. 16/182,224, titled SURGICAL NETWORK, INSTRUMENT, AND CLOUD RESPONSES BASED ON VALIDATION OF RECEIVED DATASET AND AUTHENTICATION OF ITS SOURCE AND INTEGRITY, now U.S. Patent Application Publication No. 2019/0205441; [0033] U.S. patent application Ser. No. 16/182,230, titled SURGICAL SYSTEM FOR PRESENTING INFORMATION INTERPRETED FROM EXTERNAL DATA, now U.S. Patent Application Publication No. 2019/0200980; [0034] U.S. patent application Ser. No. 16/182,233, titled MODIFICATION OF SURGICAL SYSTEMS CONTROL PROGRAMS BASED ON MACHINE LEARNING, now U.S. Patent Application Publication No. 2019/0201123; [0035] U.S. patent application Ser. No. 16/182,239, titled ADJUSTMENT OF DEVICE CONTROL PROGRAMS BASED ON STRATIFIED CONTEXTUAL DATA IN ADDITION TO THE DATA, now U.S. Patent Application Publication No. 2019/0201124; [0036] U.S. patent application Ser. No. 16/182,243, titled SURGICAL HUB AND MODULAR DEVICE RESPONSE ADJUSTMENT BASED ON SITUATIONAL AWARENESS, now U.S. Patent Application Publication No. 2019/0206542; [0037] U.S. patent application Ser. No. 16/182,248, titled DETECTION AND ESCALATION OF SECURITY RESPONSES OF SURGICAL INSTRUMENTS TO INCREASING SEVERITY THREATS, now

U.S. Patent Application Publication No. 2019/0206216; [0038] U.S. patent application Ser. No. 16/182,251, titled INTERACTIVE SURGICAL SYSTEM, now U.S. Patent Application Publication No. 2019/0201125; [0039] U.S. patent application Ser. No. 16/182,260, titled AUTOMATED DATA SCALING, ALIGNMENT, AND ORGANIZING BASED ON PREDEFINED PARAMETERS WITHIN SURGICAL NETWORKS, now U.S. Patent Application Publication No. 2019/0206576; [0040] U.S. patent application Ser. No. 16/182,267, titled SENSING THE PATIENT POSITION AND CONTACT UTILIZING THE MONO-POLAR RETURN PAD ELECTRODE TO PROVIDE SITUATIONAL AWARENESS TO A SURGICAL NETWORK, now U.S. Patent Application Publication No. 2019/0201128; [0041] U.S. patent application Ser. No. 16/182,249, titled POWERED SURGICAL TOOL WITH PREDEFINED ADJUSTABLE CONTROL ALGORITHM FOR CONTROLLING END EFFECTOR PARAMETER, now U.S. Patent Application Publication No. 2019/0201081; [0042] U.S. patent application Ser. No. 16/182,246, titled ADJUSTMENTS BASED ON AIRBORNE PARTICLE PROPERTIES, now U.S. Patent Application Publication No. 2019/0204201; [0043] U.S. patent application Ser. No. 16/182,256, titled ADJUSTMENT OF A SURGICAL DEVICE FUNCTION BASED ON SITUATIONAL AWARENESS, now U.S. Patent Application Publication No. 2019/0201127; [0044] U.S. patent application Ser. No. 16/182,242, titled REAL-TIME ANALYSIS OF COMPREHENSIVE COST OF ALL INSTRUMENTATION USED IN SURGERY UTILIZING DATA FLUIDITY TO TRACK INSTRUMENTS THROUGH STOCKING AND IN-HOUSE PROCESSES, now U.S. Patent Application Publication No. 2019/0206556; [0045] U.S. patent application Ser. No. 16/182,255, titled USAGE AND TECHNIQUE ANALYSIS OF SURGEON/STAFF PERFORMANCE AGAINST A BASELINE TO OPTIMIZE DEVICE UTILIZATION AND PERFORMANCE FOR BOTH CURRENT AND FUTURE PROCEDURES, now U.S. Patent Application Publication No. 2019/0201126; [0046] U.S. patent application Ser. No. 16/182,269, titled IMAGE CAPTURING OF THE AREAS OUTSIDE THE ABDOMEN TO IMPROVE PLACEMENT AND CONTROL OF A SURGICAL DEVICE IN USE, now U.S. Patent Application Publication No. 2019/0201129; [0047] U.S. patent application Ser. No. 16/182,278, titled COMMUNICATION OF DATA WHERE A SURGICAL NETWORK IS USING CONTEXT OF THE DATA AND REQUIREMENTS OF A RECEIVING SYSTEM/USER TO INFLUENCE INCLUSION OR LINKAGE OF DATA AND METADATA TO ESTABLISH CONTINUITY, now U.S. Patent Application Publication No. 2019/0201130; [0048] U.S. patent application Ser. No. 16/182,232, titled CONTROL OF A SURGICAL SYSTEM THROUGH A SURGICAL BARRIER, now U.S. Patent Application Publication No. 2019/0201158; [0049] U.S. patent application Ser. No. 16/182,227, titled SURGICAL NETWORK DETERMINATION OF PRIORITIZATION OF COMMUNICATION, INTERACTION, OR PROCESSING BASED ON SYSTEM OR DEVICE NEEDS, now U.S. Pat. No. 10,892,995; [0050] U.S. patent application Ser. No. 16/182,231, titled WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES, now U.S. Pat. No. 10,758,310; [0051] U.S. patent application Ser. No. 16/182,229, titled ADJUSTMENT OF STAPLE HEIGHT OF AT LEAST ONE ROW OF STAPLES BASED ON THE SENSED TISSUE THICKNESS OR FORCE IN CLOSING, now U.S. Patent Application Publication No. 2019/0200996; [0052] U.S. patent application Ser. No. 16/182,234, titled STAPLING DEVICE WITH BOTH COMPULSORY AND DISCRETIONARY LOCKOUTS BASED ON SENSED PARAMETERS, now U.S. Patent Application Publication No. 2019/0200997; [0053] U.S. patent application Ser. No. 16/182,240, titled POWERED STAPLING DEVICE CONFIGURED TO ADJUST FORCE, ADVANCEMENT SPEED, AND OVERALL STROKE OF CUTTING MEMBER BASED ON SENSED PARAMETER OF FIRING OR CLAMPING, now U.S. Patent Application Publication No. 2019/0201034; [0054] U.S. patent application Ser. No. 16/182,235, titled VARIATION OF RADIO FREQUENCY AND ULTRASONIC POWER LEVEL IN COOPERATION WITH VARYING

CLAMP ARM PRESSURE TO ACHIEVE PREDEFINED HEAT FLUX OR POWER APPLIED TO TISSUE, now U.S. Patent Application Publication No. 2019/0201044; and [0055] U.S. patent application Ser. No. 16/182,238, titled ULTRASONIC ENERGY DEVICE WHICH VARIES PRESSURE APPLIED BY CLAMP ARM TO PROVIDE THRESHOLD CONTROL PRESSURE AT A CUT PROGRESSION LOCATION, now U.S. Patent Application Publication No. 2019/0201080.

[0056] Applicant of the present application owns the following U.S. patent applications, filed on Sep. 10, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0057] U.S. Provisional Patent Application Ser. No. 62/729,183, titled A CONTROL FOR A SURGICAL NETWORK OR SURGICAL NETWORK CONNECTED DEVICE THAT ADJUSTS ITS FUNCTION BASED ON A SENSED SITUATION OR USAGE; [0058] U.S. Provisional Patent Application Ser. No. 62/729,177, titled AUTOMATED DATA SCALING, ALIGNMENT, AND ORGANIZING BASED ON PREDEFINED PARAMETERS WITHIN A SURGICAL NETWORK BEFORE TRANSMISSION; [0059] U.S. Provisional Patent Application Ser. No. 62/729,176, titled INDIRECT COMMAND AND CONTROL OF A FIRST OPERATING ROOM SYSTEM THROUGH THE USE OF A SECOND OPERATING ROOM SYSTEM WITHIN A STERILE FIELD WHERE THE SECOND OPERATING ROOM SYSTEM HAS PRIMARY AND SECONDARY OPERATING MODES; [0060] U.S. Provisional Patent Application Ser. No. 62/729,185, titled POWERED STAPLING DEVICE THAT IS CAPABLE OF ADJUSTING FORCE, ADVANCEMENT SPEED, AND OVERALL STROKE OF CUTTING MEMBER OF THE DEVICE BASED ON SENSED PARAMETER OF FIRING OR CLAMPING; [0061] U.S. Provisional Patent Application Ser. No. 62/729,184, titled POWERED SURGICAL TOOL WITH A PREDEFINED ADJUSTABLE CONTROL ALGORITHM FOR CONTROLLING AT LEAST ONE END EFFECTOR PARAMETER AND A MEANS FOR LIMITING THE ADJUSTMENT; [0062] U.S. Provisional Patent Application Ser. No. 62/729,182, titled SENSING THE PATIENT POSITION AND CONTACT UTILIZING THE MONO POLAR RETURN PAD ELECTRODE TO PROVIDE SITUATIONAL AWARENESS TO THE HUB; [0063] U.S. Provisional Patent Application Ser. No. 62/729,191, titled SURGICAL NETWORK RECOMMENDATIONS FROM REAL TIME ANALYSIS OF PROCEDURE VARIABLES AGAINST A BASELINE HIGHLIGHTING DIFFERENCES FROM THE OPTIMAL SOLUTION; [0064] U.S. Provisional Patent Application Ser. No. 62/729,195, titled ULTRASONIC ENERGY DEVICE WHICH VARIES PRESSURE APPLIED BY CLAMP ARM TO PROVIDE THRESHOLD CONTROL PRESSURE AT A CUT PROGRESSION LOCATION; and [0065] U.S. Provisional Patent Application Ser. No. 62/729,186, titled WIRELESS PAIRING OF A SURGICAL DEVICE WITH ANOTHER DEVICE WITHIN A STERILE SURGICAL FIELD BASED ON THE USAGE AND SITUATIONAL AWARENESS OF DEVICES.

[0066] Applicant of the present application owns the following U.S. patent applications, filed on Aug. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0067] U.S. patent application Ser. No. 16/115,214, titled ESTIMATING STATE OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR, now U.S. Patent Application Publication No. 2019/0201073; [0068] U.S. patent application Ser. No. 16/115,205, titled TEMPERATURE CONTROL OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR, now U.S. Patent Application Publication No. 2019/0201036; [0069] U.S. patent application Ser. No. 16/115,233, titled RADIO FREQUENCY ENERGY DEVICE FOR DELIVERING COMBINED ELECTRICAL SIGNALS, now U.S. Patent Application Publication No. 2019/0201091; [0070] U.S. patent application Ser. No. 16/115,208, titled CONTROLLING AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO TISSUE LOCATION, now U.S. Patent Application Publication No. 2019/0201037; [0071] U.S. patent application Ser. No. 16/115,220, titled CONTROLLING ACTIVATION OF AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO THE PRESENCE OF TISSUE, now U.S. Patent Application

Publication No. 2019/0201040; [0072] U.S. patent application Ser. No. 16/115,232, titled DETERMINING TISSUE COMPOSITION VIA AN ULTRASONIC SYSTEM, now U.S. Patent Application Publication No. 2019/0201038; [0073] U.S. patent application Ser. No. 16/115,239, titled DETERMINING THE STATE OF AN ULTRASONIC ELECTROMECHANICAL SYSTEM ACCORDING TO FREQUENCY SHIFT, now U.S. Patent Application Publication No. 2019/0201042; [0074] U.S. patent application Ser. No. 16/115,247, titled DETERMINING THE STATE OF AN ULTRASONIC END EFFECTOR, now U.S. Patent Application Publication No. 2019/0274716; [0075] U.S. patent application Ser. No. 16/115,211, titled SITUATIONAL AWARENESS OF ELECTROSURGICAL SYSTEMS, now U.S. Patent Application Publication No. 2019/0201039; [0076] U.S. patent application Ser. No. 16/115,226, titled MECHANISMS FOR CONTROLLING DIFFERENT ELECTROMECHANICAL SYSTEMS OF AN ELECTROSURGICAL INSTRUMENT, now U.S. Patent Application Publication No. 2019/0201075; [0077] U.S. patent application Ser. No. 16/115,240, titled DETECTION OF END EFFECTOR IMMERSION IN LIQUID, now U.S. Patent Application Publication No. 2019/0201043; [0078] U.S. patent application Ser. No. 16/115,249, titled INTERRUPTION OF ENERGY DUE TO INADVERTENT CAPACITIVE COUPLING, now U.S. Patent Application Publication No. 2019/0201077; [0079] U.S. patent application Ser. No. 16/115,256, titled INCREASING RADIO FREQUENCY TO CREATE PAD-LESS MONOPOLAR LOOP, now U.S. Patent Application Publication No. 2019/0201092; [0080] U.S. patent application Ser. No. 16/115,223, titled BIPOLAR COMBINATION DEVICE THAT AUTOMATICALLY ADJUSTS PRESSURE BASED ON ENERGY MODALITY, now U.S. Patent Application Publication No. 2019/0201074; and [0081] U.S. patent application Ser. No. 16/115,238, titled ACTIVATION OF ENERGY DEVICES, now U.S. Patent Application Publication No. 2019/0201041.

[0082] Applicant of the present application owns the following U.S. patent applications, filed on Aug. 23, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0083] U.S. Provisional Patent Application Ser. No. 62/721,995, titled CONTROLLING AN ULTRASONIC SURGICAL INSTRUMENT ACCORDING TO TISSUE LOCATION; [0084] U.S. Provisional Patent Application Ser. No. 62/721,998, titled SITUATIONAL AWARENESS OF ELECTROSURGICAL SYSTEMS; [0085] U.S. Provisional Patent Application Ser. No. 62/721,999, titled INTERRUPTION OF ENERGY DUE TO INADVERTENT CAPACITIVE COUPLING; [0086] U.S. Provisional Patent Application Ser. No. 62/721,994, titled BIPOLAR COMBINATION DEVICE THAT AUTOMATICALLY ADJUSTS PRESSURE BASED ON ENERGY MODALITY; and [0087] U.S. Provisional Patent Application Ser. No. 62/721,996, titled RADIO FREQUENCY ENERGY DEVICE FOR DELIVERING COMBINED ELECTRICAL SIGNALS.

[0088] Applicant of the present application owns the following U.S. patent applications, filed on Jun. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0089] U.S. Provisional Patent Application Ser. No. 62/692,747, titled SMART ACTIVATION OF AN ENERGY DEVICE BY ANOTHER DEVICE; [0090] U.S. Provisional Patent Application Ser. No. 62/692,748, titled SMART ENERGY ARCHITECTURE; and [0091] U.S. Provisional Patent Application Ser. No. 62/692,768, titled SMART ENERGY DEVICES.

[0092] Applicant of the present application owns the following U.S. patent applications, filed on Jun. 29, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0093] U.S. patent application Ser. No. 16/024,090, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS, now U.S. Patent Application Publication No. 2019/0201090; [0094] U.S. patent application Ser. No. 16/024,057, titled CONTROLLING A SURGICAL INSTRUMENT ACCORDING TO SENSED CLOSURE PARAMETERS, now U.S. Pat. No. 10,695,081; [0095] U.S. patent application Ser. No. 16/024,067, titled SYSTEMS FOR ADJUSTING END EFFECTOR PARAMETERS BASED ON PERIOPERATIVE INFORMATION, now U.S. Pat. No. 10,595,887; [0096] U.S. patent application Ser. No.

16/024,075, titled SAFETY SYSTEMS FOR SMART POWERED SURGICAL STAPLING, now U.S. Patent Application Publication No. 2019/0201146; [0097] U.S. patent application Ser. No. 16/024,083, titled SAFETY SYSTEMS FOR SMART POWERED SURGICAL STAPLING, now U.S. Patent Application Publication No. 2019/0200984; [0098] U.S. patent application Ser. No. 16/024,094, titled SURGICAL SYSTEMS FOR DETECTING END EFFECTOR TISSUE DISTRIBUTION IRREGULARITIES, now U.S. Patent Application Publication No. 2019/0201020; [0099] U.S. patent application Ser. No. 16/024,138, titled SYSTEMS FOR DETECTING PROXIMITY OF SURGICAL END EFFECTOR TO CANCEROUS TISSUE, now U.S. Patent Application Publication No. 2019/0200985; [0100] U.S. patent application Ser. No. 16/024,150, titled SURGICAL INSTRUMENT CARTRIDGE SENSOR ASSEMBLIES, now U.S. Patent Application Publication No. 2019/0200986; [0101] U.S. patent application Ser. No. 16/024,160, titled VARIABLE OUTPUT CARTRIDGE SENSOR ASSEMBLY, now U.S. Patent Application Publication No. 2019/0200987; [0102] U.S. patent application Ser. No. 16/024,124, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE ELECTRODE, now U.S. Patent Application Publication No. 2019/0201079; [0103] U.S. patent application Ser. No. 16/024,132, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE CIRCUIT, now U.S. Patent Application Publication No. 2019/0201021; [0104] U.S. patent application Ser. No. 16/024,141, titled SURGICAL INSTRUMENT WITH A TISSUE MARKING ASSEMBLY, now U.S. Patent Application Publication No. 2019/0201159; [0105] U.S. patent application Ser. No. 16/024,162, titled SURGICAL SYSTEMS WITH PRIORITIZED DATA TRANSMISSION CAPABILITIES, now U.S. Patent Application Publication No. 2019/0200988; [0106] U.S. patent application Ser. No. 16/024,066, titled SURGICAL EVACUATION SENSING AND MOTOR CONTROL, now U.S. Patent Application Publication No. 2019/0201082; [0107] U.S. patent application Ser. No. 16/024,096, titled SURGICAL EVACUATION SENSOR ARRANGEMENTS, now U.S. Patent Application Publication No. 2019/0201083; [0108] U.S. patent application Ser. No. 16/024,116, titled SURGICAL EVACUATION FLOW PATHS, now U.S. Patent Application Publication No. 2019/0201084; [0109] U.S. patent application Ser. No. 16/024,149, titled SURGICAL EVACUATION SENSING AND GENERATOR CONTROL, now U.S. Patent Application Publication No. 2019/0201085; [0110] U.S. patent application Ser. No. 16/024,180, titled SURGICAL EVACUATION SENSING AND DISPLAY, now U.S. Patent Application Publication No. 2019/0201086; [0111] U.S. patent application Ser. No. 16/024,245, titled COMMUNICATION OF SMOKE EVACUATION SYSTEM PARAMETERS TO HUB OR CLOUD IN SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM, now U.S. Pat. No. 10,755,813; [0112] U.S. patent application Ser. No. 16/024,258, titled SMOKE EVACUATION SYSTEM INCLUDING A SEGMENTED CONTROL CIRCUIT FOR INTERACTIVE SURGICAL PLATFORM, now U.S. Patent Application Publication No. 2019/0201087; [0113] U.S. patent application Ser. No. 16/024,265, titled SURGICAL EVACUATION SYSTEM WITH A COMMUNICATION CIRCUIT FOR COMMUNICATION BETWEEN A FILTER AND A SMOKE EVACUATION DEVICE, now U.S. Pat. No. 10,898,622; and [0114] U.S. patent application Ser. No. 16/024,273, titled DUAL IN-SERIES LARGE AND SMALL DROPLET FILTERS, now U.S. Patent Application Publication No. 2019/0201597.

[0115] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Jun. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0116] U.S. Provisional Patent Application Ser. No. 62/691,228, titled A METHOD OF USING REINFORCED FLEX CIRCUITS WITH MULTIPLE SENSORS WITH ELECTROSURGICAL DEVICES; [0117] U.S. Provisional Patent Application Ser. No. 62/691,227, titled CONTROLLING A SURGICAL INSTRUMENT ACCORDING TO SENSED CLOSURE PARAMETERS; [0118] U.S. Provisional Patent Application Ser. No. 62/691,230, titled SURGICAL INSTRUMENT HAVING A FLEXIBLE ELECTRODE; [0119] U.S. Provisional Patent Application Ser. No. 62/691,219, titled SURGICAL EVACUATION SENSING AND

MOTOR CONTROL; [0120] U.S. Provisional Patent Application Ser. No. 62/691,257, titled COMMUNICATION OF SMOKE EVACUATION SYSTEM PARAMETERS TO HUB OR CLOUD IN SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM; [0121] U.S. Provisional Patent Application Ser. No. 62/691,262, titled SURGICAL EVACUATION SYSTEM WITH A COMMUNICATION CIRCUIT FOR COMMUNICATION BETWEEN A FILTER AND A SMOKE EVACUATION DEVICE; and [0122] U.S. Provisional Patent Application Ser. No. 62/691,251, titled DUAL IN-SERIES LARGE AND SMALL DROPLET FILTERS.

[0123] Applicant of the present application owns the following U.S. Provisional Patent Application, filed on Apr. 19, 2018, the disclosure of which is herein incorporated by reference in its entirety: [0124] U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION.

[0125] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 30, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0126] U.S. Provisional Patent Application Ser. No. 62/650,898 filed on Mar. 30, 2018, titled CAPACITIVE COUPLED RETURN PATH PAD WITH SEPARABLE ARRAY ELEMENTS; [0127] U.S. Provisional Patent Application Ser. No. 62/650,887, titled SURGICAL SYSTEMS WITH OPTIMIZED SENSING CAPABILITIES; [0128] U.S. Provisional Patent Application Ser. No. 62/650,882, titled SMOKE EVACUATION MODULE FOR INTERACTIVE SURGICAL PLATFORM; and [0129] U.S. Provisional Patent Application Ser. No. 62/650,877, titled SURGICAL SMOKE EVACUATION SENSING AND CONTROLS.

[0130] Applicant of the present application owns the following U.S. patent applications, filed on Mar. 29, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0131] U.S. patent application Ser. No. 15/940,641, titled INTERACTIVE SURGICAL SYSTEMS WITH ENCRYPTED COMMUNICATION CAPABILITIES, now U.S. Pat. No. 10,944,728; [0132] U.S. patent application Ser. No. 15/940,648, titled INTERACTIVE SURGICAL SYSTEMS WITH CONDITION HANDLING OF DEVICES AND DATA CAPABILITIES, now U.S. Patent Application Publication No. 2019/0206004; [0133] U.S. patent application Ser. No. 15/940,656, titled SURGICAL HUB COORDINATION OF CONTROL AND COMMUNICATION OF OPERATING ROOM DEVICES, now U.S. Patent Application Publication No. 2019/0201141; [0134] U.S. patent application Ser. No. 15/940,666, titled SPATIAL AWARENESS OF SURGICAL HUBS IN OPERATING ROOMS, now U.S. Patent Application Publication No. 2019/0206551; [0135] U.S. patent application Ser. No. 15/940,670, titled COOPERATIVE UTILIZATION OF DATA DERIVED FROM SECONDARY SOURCES BY INTELLIGENT SURGICAL HUBS, now U.S. Patent Application Publication No. 2019/0201116; [0136] U.S. patent application Ser. No. 15/940,677, titled SURGICAL HUB CONTROL ARRANGEMENTS, now U.S. Patent Application Publication No. 2019/0201143; [0137] U.S. patent application Ser. No. 15/940,632, titled DATA STRIPPING METHOD TO INTERROGATE PATIENT RECORDS AND CREATE ANONYMIZED RECORD, now U.S. Patent Application Publication No. 2019/0205566; [0138] U.S. patent application Ser. No. 15/940,640, titled COMMUNICATION HUB AND STORAGE DEVICE FOR STORING PARAMETERS AND STATUS OF A SURGICAL DEVICE TO BE SHARED WITH CLOUD BASED ANALYTICS SYSTEMS, now U.S. Patent Application Publication No. 2019/0200863; [0139] U.S. patent application Ser. No. 15/940,645, titled SELF DESCRIBING DATA PACKETS GENERATED AT AN ISSUING INSTRUMENT, now U.S. Pat. No. 10,892,899; [0140] U.S. patent application Ser. No. 15/940,649, titled DATA PAIRING TO INTERCONNECT A DEVICE MEASURED PARAMETER WITH AN OUTCOME, now U.S. Patent Application Publication No. 2019/0205567; [0141] U.S. patent application Ser. No. 15/940,654, titled SURGICAL HUB SITUATIONAL AWARENESS, now U.S. Patent Application Publication No. 2019/0201140; [0142] U.S. patent application Ser. No. 15/940,663, titled SURGICAL SYSTEM DISTRIBUTED PROCESSING, now U.S. Patent Application Publication

No. 2019/0201033; [0143] U.S. patent application Ser. No. 15/940,668, titled AGGREGATION AND REPORTING OF SURGICAL HUB DATA, now U.S. Patent Application Publication No. 2019/0201115; [0144] U.S. patent application Ser. No. 15/940,671, titled SURGICAL HUB SPATIAL AWARENESS TO DETERMINE DEVICES IN OPERATING THEATER, now U.S. Patent Application Publication No. 2019/0201104; [0145] U.S. patent application Ser. No. 15/940,686, titled DISPLAY OF ALIGNMENT OF STAPLE CARTRIDGE TO PRIOR LINEAR STAPLE LINE, now U.S. Patent Application Publication No. 2019/0201105; [0146] U.S. patent application Ser. No. 15/940,700, titled STERILE FIELD INTERACTIVE CONTROL DISPLAYS, now U.S. Patent Application Publication No. 2019/0205001; [0147] U.S. patent application Ser. No. 15/940,629, titled COMPUTER IMPLEMENTED INTERACTIVE SURGICAL SYSTEMS, now U.S. Patent Application Publication No. 2019/0201112; [0148] U.S. patent application Ser. No. 15/940,704, titled USE OF LASER LIGHT AND RED-GREEN-BLUE COLORATION TO DETERMINE PROPERTIES OF BACK SCATTERED LIGHT, now U.S. Patent Application Publication No. 2019/0206050; [0149] U.S. patent application Ser. No. 15/940,722, titled CHARACTERIZATION OF TISSUE IRREGULARITIES THROUGH THE USE OF MONO-CHROMATIC LIGHT REFRACTIVITY, now U.S. Patent Application Publication No. 2019/0200905; [0150] U.S. patent application Ser. No. 15/940,742, titled DUAL CMOS ARRAY IMAGING, now U.S. Patent Application Publication No. 2019/0200906; [0151] U.S. patent application Ser. No. 15/940,636, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL DEVICES, now U.S. Patent Application Publication No. 2019/0206003; [0152] U.S. patent application Ser. No. 15/940,653, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL HUBS, now U.S. Patent Application Publication No. 2019/0201114; [0153] U.S. patent application Ser. No. 15/940,660, titled CLOUD-BASED MEDICAL ANALYTICS FOR CUSTOMIZATION AND RECOMMENDATIONS TO A USER, now U.S. Patent Application Publication No. 2019/0206555; [0154] U.S. patent application Ser. No. 15/940,679, titled CLOUD-BASED MEDICAL ANALYTICS FOR LINKING OF LOCAL USAGE TRENDS WITH THE RESOURCE ACQUISITION BEHAVIORS OF LARGER DATA SET, now U.S. Pat. No. 10,932,872; [0155] U.S. patent application Ser. No. 15/940,694, titled CLOUD-BASED MEDICAL ANALYTICS FOR MEDICAL FACILITY SEGMENTED INDIVIDUALIZATION OF INSTRUMENT FUNCTION, now U.S. Patent Application Publication No. 2019/0201119; [0156] U.S. patent application Ser. No. 15/940,634, titled CLOUD-BASED MEDICAL ANALYTICS FOR SECURITY AND AUTHENTICATION TRENDS AND REACTIVE MEASURES, now U.S. Patent Application Publication No. 2019/0201138; [0157] U.S. patent application Ser. No. 15/940,706, titled DATA HANDLING AND PRIORITIZATION IN A CLOUD ANALYTICS NETWORK, now U.S. Patent Application Publication No. 2019/0206561; [0158] U.S. patent application Ser. No. 15/940,675, titled CLOUD INTERFACE FOR COUPLED SURGICAL DEVICES, now U.S. Pat. No. 10,849,697; [0159] U.S. patent application Ser. No. 15/940,627, titled DRIVE ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201111; [0160] U.S. patent application Ser. No. 15/940,637, titled COMMUNICATION ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201139; [0161] U.S. patent application Ser. No. 15/940,642, titled CONTROLS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201113; [0162] U.S. patent application Ser. No. 15/940,676, titled AUTOMATIC TOOL ADJUSTMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201142; [0163] U.S. patent application Ser. No. 15/940,680, titled CONTROLLERS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201135; [0164] U.S. patent application Ser. No. 15/940,683, titled COOPERATIVE SURGICAL ACTIONS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201145; [0165] U.S. patent application Ser. No. 15/940,690,

titled DISPLAY ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201118; and [0166] U.S. patent application Ser. No. 15/940,711, titled SENSING ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS, now U.S. Patent Application Publication No. 2019/0201120.

[0167] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 28, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0168] U.S. Provisional Patent Application Ser. No. 62/649,302, titled INTERACTIVE SURGICAL SYSTEMS WITH ENCRYPTED COMMUNICATION CAPABILITIES; [0169] U.S. Provisional Patent Application Ser. No. 62/649,294, titled DATA STRIPPING METHOD TO INTERROGATE PATIENT RECORDS AND CREATE ANONYMIZED RECORD; [0170] U.S. Provisional Patent Application Ser. No. 62/649,300, titled SURGICAL HUB SITUATIONAL AWARENESS; [0171] U.S. Provisional Patent Application Ser. No. 62/649,309, titled SURGICAL HUB SPATIAL AWARENESS TO DETERMINE DEVICES IN OPERATING THEATER; [0172] U.S. Provisional Patent Application Ser. No. 62/649,310, titled COMPUTER IMPLEMENTED INTERACTIVE SURGICAL SYSTEMS; [0173] U.S. Provisional Patent Application Ser. No. 62/649,291, titled USE OF LASER LIGHT AND RED-GREEN-BLUE COLORATION TO DETERMINE PROPERTIES OF BACK SCATTERED LIGHT; [0174] U.S. Provisional Patent Application Ser. No. 62/649,296, titled ADAPTIVE CONTROL PROGRAM UPDATES FOR SURGICAL DEVICES; [0175] U.S. Provisional Patent Application Ser. No. 62/649,333, titled CLOUD-BASED MEDICAL ANALYTICS FOR CUSTOMIZATION AND RECOMMENDATIONS TO A USER; [0176] U.S. Provisional Patent Application Ser. No. 62/649,327, titled CLOUD-BASED MEDICAL ANALYTICS FOR SECURITY AND AUTHENTICATION TRENDS AND REACTIVE MEASURES; [0177] U.S. Provisional Patent Application Ser. No. 62/649,315, titled DATA HANDLING AND PRIORITIZATION IN A CLOUD ANALYTICS NETWORK; [0178] U.S. Provisional Patent Application Ser. No. 62/649,313, titled CLOUD INTERFACE FOR COUPLED SURGICAL DEVICES; [0179] U.S. Provisional Patent Application Ser. No. 62/649,320, titled DRIVE ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS; [0180] U.S. Provisional Patent Application Ser. No. 62/649,307, titled AUTOMATIC TOOL ADJUSTMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS; and [0181] U.S. Provisional Patent Application Ser. No. 62/649,323, titled SENSING ARRANGEMENTS FOR ROBOT-ASSISTED SURGICAL PLATFORMS.

[0182] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Mar. 8, 2018, the disclosure of each of which is herein incorporated by reference in its entirety: [0183] U.S. Provisional Patent Application Ser. No. 62/640,417, titled TEMPERATURE CONTROL IN ULTRASONIC DEVICE AND CONTROL SYSTEM THEREFOR; and [0184] U.S. Provisional Patent Application Ser. No. 62/640,415, titled ESTIMATING STATE OF ULTRASONIC END EFFECTOR AND CONTROL SYSTEM THEREFOR.

[0185] Applicant of the present application owns the following U.S. Provisional Patent Applications, filed on Dec. 28, 2017, the disclosure of each of which is herein incorporated by reference in its entirety: [0186] U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM; [0187] U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS; and [0188] U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM.

[0189] Before explaining various aspects of surgical devices and generators in detail, it should be noted that the illustrative examples are not limited in application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative examples may be implemented or incorporated in other aspects, variations and modifications, and may be practiced or carried out in various ways. Further, unless otherwise

indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative examples for the convenience of the reader and are not for the purpose of limitation thereof. Also, it will be appreciated that one or more of the following-described aspects, expressions of aspects, and/or examples, can be combined with any one or more of the other following-described aspects, expressions of aspects and/or examples.

Surgical Hubs

[0190] Referring to FIG. **1**, a computer-implemented interactive surgical system **100** includes one or more surgical systems **102** and a cloud-based system (e.g., the cloud **104** that may include a remote server **113** coupled to a storage device **105**). Each surgical system **102** includes at least one surgical hub **106** in communication with the cloud **104** that may include a remote server **113**. In one example, as illustrated in FIG. **1**, the surgical system **102** includes a visualization system **108**, a robotic system **110**, and a handheld intelligent surgical instrument **112**, which are configured to communicate with one another and/or the hub **106**. In some aspects, a surgical system **102** may include an M number of hubs **106**, an N number of visualization systems **108**, an O number of robotic systems **110**, and a P number of handheld intelligent surgical instruments **112**, where M, N, O, and P are integers greater than or equal to one.

[0191] FIG. **2** depicts an example of a surgical system **102** being used to perform a surgical procedure on a patient who is lying down on an operating table **114** in a surgical operating room **116**. A robotic system **110** is used in the surgical procedure as a part of the surgical system **102**. The robotic system **110** includes a surgeon's console **118**, a patient side cart **120** (surgical robot), and a surgical robotic hub **122**. The patient side cart **120** can manipulate at least one removably coupled surgical tool **117** through a minimally invasive incision in the body of the patient while the surgeon views the surgical site through the surgeon's console **118**. An image of the surgical site can be obtained by a medical imaging device **124**, which can be manipulated by the patient side cart **120** to orient the imaging device **124**. The robotic hub **122** can be used to process the images of the surgical site for subsequent display to the surgeon through the surgeon's console **118**.

[0192] Other types of robotic systems can be readily adapted for use with the surgical system **102**. Various examples of robotic systems and surgical tools that are suitable for use with the present disclosure are described in U.S. Provisional Patent Application Ser. No. 62/611,339, titled ROBOT ASSISTED SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0193] Various examples of cloud-based analytics that are performed by the cloud **104**, and are suitable for use with the present disclosure, are described in U.S. Provisional Patent Application Ser. No. 62/611,340, titled CLOUD-BASED MEDICAL ANALYTICS, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0194] In various aspects, the imaging device **124** includes at least one image sensor and one or more optical components. Suitable image sensors include, but are not limited to, Charge-Coupled Device (CCD) sensors and Complementary Metal-Oxide Semiconductor (CMOS) sensors.

[0195] The optical components of the imaging device **124** may include one or more illumination sources and/or one or more lenses. The one or more illumination sources may be directed to illuminate portions of the surgical field. The one or more image sensors may receive light reflected or refracted from the surgical field, including light reflected or refracted from tissue and/or surgical instruments.

[0196] The one or more illumination sources may be configured to radiate electromagnetic energy in the visible spectrum as well as the invisible spectrum. The visible spectrum, sometimes referred to as the optical spectrum or luminous spectrum, is that portion of the electromagnetic spectrum that is visible to (i.e., can be detected by) the human eye and may be referred to as visible light or simply light. A typical human eye will respond to wavelengths in air that are from about 380 nm to about 750 nm.

[0197] The invisible spectrum (i.e., the non-luminous spectrum) is that portion of the

electromagnetic spectrum that lies below and above the visible spectrum (i.e., wavelengths below about 380 nm and above about 750 nm). The invisible spectrum is not detectable by the human eye. Wavelengths greater than about 750 nm are longer than the red visible spectrum, and they become invisible infrared (IR), microwave, and radio electromagnetic radiation. Wavelengths less than about 380 nm are shorter than the violet spectrum, and they become invisible ultraviolet, x-ray, and gamma ray electromagnetic radiation.

[0198] In various aspects, the imaging device **124** is configured for use in a minimally invasive procedure. Examples of imaging devices suitable for use with the present disclosure include, but not limited to, an arthroscope, angioscope, bronchoscope, choledochoscope, colonoscope, cytoscope, duodenoscope, enteroscope, esophagogastro-duodenoscope (gastroscope), endoscope, laryngoscope, nasopharyngo-neproscope, sigmoidoscope, thoracoscope, and ureteroscope.

[0199] In one aspect, the imaging device employs multi-spectrum monitoring to discriminate topography and underlying structures. A multi-spectral image is one that captures image data within specific wavelength ranges across the electromagnetic spectrum. The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, e.g., IR and ultraviolet. Spectral imaging can allow extraction of additional information the human eye fails to capture with its receptors for red, green, and blue. The use of multi-spectral imaging is described in greater detail under the heading "Advanced Imaging Acquisition Module" in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety. Multi-spectrum monitoring can be a useful tool in relocating a surgical field after a surgical task is completed to perform one or more of the previously described tests on the treated tissue.

[0200] It is axiomatic that strict sterilization of the operating room and surgical equipment is required during any surgery. The strict hygiene and sterilization conditions required in a "surgical theater," i.e., an operating or treatment room, necessitate the highest possible sterility of all medical devices and equipment. Part of that sterilization process is the need to sterilize anything that comes in contact with the patient or penetrates the sterile field, including the imaging device **124** and its attachments and components. It will be appreciated that the sterile field may be considered a specified area, such as within a tray or on a sterile towel, that is considered free of microorganisms, or the sterile field may be considered an area, immediately around a patient, who has been prepared for a surgical procedure. The sterile field may include the scrubbed team members, who are properly attired, and all furniture and fixtures in the area.

[0201] In various aspects, the visualization system **108** includes one or more imaging sensors, one or more image-processing units, one or more storage arrays, and one or more displays that are strategically arranged with respect to the sterile field, as illustrated in FIG. **2**. In one aspect, the visualization system **108** includes an interface for HL7, PACS, and EMR. Various components of the visualization system **108** are described under the heading "Advanced Imaging Acquisition Module" in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety.

[0202] As illustrated in FIG. **2**, a primary display **119** is positioned in the sterile field to be visible to an operator at the operating table **114**. In addition, a visualization tower **111** is positioned outside the sterile field. The visualization tower **111** includes a first non-sterile display **107** and a second non-sterile display **109**, which face away from each other. The visualization system **108**, guided by the hub **106**, is configured to utilize the displays **107**, **109**, and **119** to coordinate information flow to operators inside and outside the sterile field. For example, the hub **106** may cause the visualization system **108** to display a snapshot of a surgical site, as recorded by an imaging device **124**, on a non-sterile display **107** or **109**, while maintaining a live feed of the surgical site on the primary display **119**. The snapshot on the non-sterile display **107** or **109** can permit a non-sterile

operator to perform a diagnostic step relevant to the surgical procedure, for example.

[0203] In one aspect, the hub **106** is also configured to route a diagnostic input or feedback entered by a non-sterile operator at the visualization tower **111** to the primary display **119** within the sterile field, where it can be viewed by a sterile operator at the operating table. In one example, the input can be in the form of a modification to the snapshot displayed on the non-sterile display **107** or **109**, which can be routed to the primary display **119** by the hub **106**.

[0204] Referring to FIG. **2**, a surgical instrument **112** is being used in the surgical procedure as part of the surgical system **102**. The hub **106** is also configured to coordinate information flow to a display of the surgical instrument **112**. For example, coordinate information flow is further described in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety. A diagnostic input or feedback entered by a non-sterile operator at the visualization tower **111** can be routed by the hub **106** to the surgical instrument display **115** within the sterile field, where it can be viewed by the operator of the surgical instrument **112**. Example surgical instruments that are suitable for use with the surgical system **102** are described under the heading "Surgical Instrument Hardware" in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, the disclosure of which is herein incorporated by reference in its entirety, for example.

[0205] Referring now to FIG. **3**, a hub **106** is depicted in communication with a visualization system **108**, a robotic system **110**, and a handheld intelligent surgical instrument **112**. The hub **106** includes a hub display **135**, an imaging module **138**, a generator module **140** (which can include a monopolar generator **142**, a bipolar generator **144**, and/or an ultrasonic generator **143**), a communication module **130**, a processor module **132**, and a storage array **134**. In certain aspects, as illustrated in FIG. **3**, the hub **106** further includes a smoke evacuation module **126**, a suction/irrigation module **128**, and/or an OR mapping module **133**.

[0206] During a surgical procedure, energy application to tissue, for sealing and/or cutting, is generally associated with smoke evacuation, suction of excess fluid, and/or irrigation of the tissue. Fluid, power, and/or data lines from different sources are often entangled during the surgical procedure. Valuable time can be lost addressing this issue during a surgical procedure. Detangling the lines may necessitate disconnecting the lines from their respective modules, which may require resetting the modules. The hub modular enclosure **136** offers a unified environment for managing the power, data, and fluid lines, which reduces the frequency of entanglement between such lines.

[0207] Aspects of the present disclosure present a surgical hub for use in a surgical procedure that involves energy application to tissue at a surgical site. The surgical hub includes a hub enclosure and a combo generator module slidably receivable in a docking station of the hub enclosure. The docking station includes data and power contacts. The combo generator module includes two or more of an ultrasonic energy generator component, a bipolar RF energy generator component, and a monopolar RF energy generator component that are housed in a single unit. In one aspect, the combo generator module also includes a smoke evacuation component, at least one energy delivery cable for connecting the combo generator module to a surgical instrument, at least one smoke evacuation component configured to evacuate smoke, fluid, and/or particulates generated by the application of therapeutic energy to the tissue, and a fluid line extending from the remote surgical site to the smoke evacuation component.

[0208] In one aspect, the fluid line is a first fluid line and a second fluid line extends from the remote surgical site to a suction and irrigation module slidably received in the hub enclosure. In one aspect, the hub enclosure comprises a fluid interface.

[0209] Certain surgical procedures may require the application of more than one energy type to the tissue. One energy type may be more beneficial for cutting the tissue, while another different energy type may be more beneficial for sealing the tissue. For example, a bipolar generator can be used to seal the tissue while an ultrasonic generator can be used to cut the sealed tissue. Aspects of

the present disclosure present a solution where a hub modular enclosure **136** is configured to accommodate different generators, and facilitate an interactive communication therebetween. One of the advantages of the hub modular enclosure **136** is enabling the quick removal and/or replacement of various modules.

[0210] Aspects of the present disclosure present a modular surgical enclosure for use in a surgical procedure that involves energy application to tissue. The modular surgical enclosure includes a first energy-generator module, configured to generate a first energy for application to the tissue, and a first docking station comprising a first docking port that includes first data and power contacts, wherein the first energy-generator module is slidably movable into an electrical engagement with the power and data contacts and wherein the first energy-generator module is slidably movable out of the electrical engagement with the first power and data contacts,

[0211] Further to the above, the modular surgical enclosure also includes a second energy-generator module configured to generate a second energy, different than the first energy, for application to the tissue, and a second docking station comprising a second docking port that includes second data and power contacts, wherein the second energy-generator module is slidably movable into an electrical engagement with the power and data contacts, and wherein the second energy-generator module is slidably movable out of the electrical engagement with the second power and data contacts.

[0212] In addition, the modular surgical enclosure also includes a communication bus between the first docking port and the second docking port, configured to facilitate communication between the first energy-generator module and the second energy-generator module.

[0213] Referring to FIGS. **3-7**, aspects of the present disclosure are presented for a hub modular enclosure **136** that allows the modular integration of a generator module **140**, a smoke evacuation module **126**, and a suction/irrigation module **128**. The hub modular enclosure **136** further facilitates interactive communication between the modules **140**, **126**, **128**. As illustrated in FIG. **5**, the generator module **140** can be a generator module with integrated monopolar, bipolar, and ultrasonic components supported in a single housing unit **139** slidably insertable into the hub modular enclosure **136**. As illustrated in FIG. **5**, the generator module **140** can be configured to connect to a monopolar device **146**, a bipolar device **147**, and an ultrasonic device **148**. Alternatively, the generator module **140** may comprise a series of monopolar, bipolar, and/or ultrasonic generator modules that interact through the hub modular enclosure **136**. The hub modular enclosure **136** can be configured to facilitate the insertion of multiple generators and interactive communication between the generators docked into the hub modular enclosure **136** so that the generators would act as a single generator.

[0214] In one aspect, the hub modular enclosure **136** comprises a modular power and communication backplane **149** with external and wireless communication headers to enable the removable attachment of the modules **140**, **126**, **128** and interactive communication therebetween.

[0215] In one aspect, the hub modular enclosure **136** includes docking stations, or drawers, **151**, herein also referred to as drawers, which are configured to slidably receive the modules **140**, **126**, **128**. FIG. **4** illustrates a partial perspective view of a surgical hub enclosure **136**, and a combo generator module **145** slidably receivable in a docking station **151** of the surgical hub enclosure **136**. A docking port **152** with power and data contacts on a rear side of the combo generator module **145** is configured to engage a corresponding docking port **150** with power and data contacts of a corresponding docking station **151** of the hub modular enclosure **136** as the combo generator module **145** is slid into position within the corresponding docking station **151** of the hub module enclosure **136**. In one aspect, the combo generator module **145** includes a bipolar, ultrasonic, and monopolar module and a smoke evacuation module integrated together into a single housing unit **139**, as illustrated in FIG. **5**.

[0216] In various aspects, the smoke evacuation module **126** includes a fluid line **154** that conveys captured/collected smoke and/or fluid away from a surgical site and to, for example, the smoke

evacuation module **126**. Vacuum suction originating from the smoke evacuation module **126** can draw the smoke into an opening of a utility conduit at the surgical site. The utility conduit, coupled to the fluid line, can be in the form of a flexible tube terminating at the smoke evacuation module **126**. The utility conduit and the fluid line define a fluid path extending toward the smoke evacuation module **126** that is received in the hub enclosure **136**.

[0217] In various aspects, the suction/irrigation module **128** is coupled to a surgical tool comprising an aspiration fluid line and a suction fluid line. In one example, the aspiration and suction fluid lines are in the form of flexible tubes extending from the surgical site toward the suction/irrigation module **128**. One or more drive systems can be configured to cause irrigation and aspiration of fluids to and from the surgical site.

[0218] In one aspect, the surgical tool includes a shaft having an end effector at a distal end thereof and at least one energy treatment associated with the end effector, an aspiration tube, and an irrigation tube. The aspiration tube can have an inlet port at a distal end thereof and the aspiration tube extends through the shaft. Similarly, an irrigation tube can extend through the shaft and can have an inlet port in proximity to the energy deliver implement. The energy deliver implement is configured to deliver ultrasonic and/or RF energy to the surgical site and is coupled to the generator module **140** by a cable extending initially through the shaft.

[0219] The irrigation tube can be in fluid communication with a fluid source, and the aspiration tube can be in fluid communication with a vacuum source. The fluid source and/or the vacuum source can be housed in the suction/irrigation module **128**. In one example, the fluid source and/or the vacuum source can be housed in the hub enclosure **136** separately from the suction/irrigation module **128**. In such example, a fluid interface can be configured to connect the suction/irrigation module **128** to the fluid source and/or the vacuum source.

[0220] In one aspect, the modules **140**, **126**, **128** and/or their corresponding docking stations on the hub modular enclosure **136** may include alignment features that are configured to align the docking ports of the modules into engagement with their counterparts in the docking stations of the hub modular enclosure **136**. For example, as illustrated in FIG. **4**, the combo generator module **145** includes side brackets **155** that are configured to slidably engage with corresponding brackets **156** of the corresponding docking station **151** of the hub modular enclosure **136**. The brackets cooperate to guide the docking port contacts of the combo generator module **145** into an electrical engagement with the docking port contacts of the hub modular enclosure **136**.

[0221] In some aspects, the drawers **151** of the hub modular enclosure **136** are the same, or substantially the same size, and the modules are adjusted in size to be received in the drawers **151**. For example, the side brackets **155** and/or **156** can be larger or smaller depending on the size of the module. In other aspects, the drawers **151** are different in size and are each designed to accommodate a particular module.

[0222] Furthermore, the contacts of a particular module can be keyed for engagement with the contacts of a particular drawer to avoid inserting a module into a drawer with mismatching contacts.

[0223] As illustrated in FIG. **4**, the docking port **150** of one drawer **151** can be coupled to the docking port **150** of another drawer **151** through a communications link **157** to facilitate an interactive communication between the modules housed in the hub modular enclosure **136**. The docking ports **150** of the hub modular enclosure **136** may alternatively, or additionally, facilitate a wireless interactive communication between the modules housed in the hub modular enclosure **136**. Any suitable wireless communication can be employed, such as for example Air Titan-Bluetooth.

[0224] FIG. **6** illustrates individual power bus attachments for a plurality of lateral docking ports of a lateral modular housing **160** configured to receive a plurality of modules of a surgical hub **206**. The lateral modular housing **160** is configured to laterally receive and interconnect the modules **161**. The modules **161** are slidably inserted into docking stations **162** of lateral modular housing **160**, which includes a backplane for interconnecting the modules **161**. As illustrated in FIG. **6**, the

modules **161** are arranged laterally in the lateral modular housing **160**. Alternatively, the modules **161** may be arranged vertically in a lateral modular housing.

[0225] FIG. **7** illustrates a vertical modular housing **164** configured to receive a plurality of modules **165** of the surgical hub **106**. The modules **165** are slidably inserted into docking stations, or drawers, **167** of vertical modular housing **164**, which includes a backplane for interconnecting the modules **165**. Although the drawers **167** of the vertical modular housing **164** are arranged vertically, in certain instances, a vertical modular housing **164** may include drawers that are arranged laterally. Furthermore, the modules **165** may interact with one another through the docking ports of the vertical modular housing **164**. In the example of FIG. **7**, a display **177** is provided for displaying data relevant to the operation of the modules **165**. In addition, the vertical modular housing **164** includes a master module **178** housing a plurality of sub-modules that are slidably received in the master module **178**.

[0226] In various aspects, the imaging module **138** comprises an integrated video processor and a modular light source and is adapted for use with various imaging devices. In one aspect, the imaging device is comprised of a modular housing that can be assembled with a light source module and a camera module. The housing can be a disposable housing. In at least one example, the disposable housing is removably coupled to a reusable controller, a light source module, and a camera module. The light source module and/or the camera module can be selectively chosen depending on the type of surgical procedure. In one aspect, the camera module comprises a CCD sensor. In another aspect, the camera module comprises a CMOS sensor. In another aspect, the camera module is configured for scanned beam imaging. Likewise, the light source module can be configured to deliver a white light or a different light, depending on the surgical procedure.

[0227] During a surgical procedure, removing a surgical device from the surgical field and replacing it with another surgical device that includes a different camera or a different light source can be inefficient. Temporarily losing sight of the surgical field may lead to undesirable consequences. The module imaging device of the present disclosure is configured to permit the replacement of a light source module or a camera module midstream during a surgical procedure, without having to remove the imaging device from the surgical field.

[0228] In one aspect, the imaging device comprises a tubular housing that includes a plurality of channels. A first channel is configured to slidably receive the camera module, which can be configured for a snap-fit engagement with the first channel. A second channel is configured to slidably receive the light source module, which can be configured for a snap-fit engagement with the second channel. In another example, the camera module and/or the light source module can be rotated into a final position within their respective channels. A threaded engagement can be employed in lieu of the snap-fit engagement.

[0229] In various examples, multiple imaging devices are placed at different positions in the surgical field to provide multiple views. The imaging module **138** can be configured to switch between the imaging devices to provide an optimal view. In various aspects, the imaging module **138** can be configured to integrate the images from the different imaging device.

[0230] Various image processors and imaging devices suitable for use with the present disclosure are described in U.S. Pat. No. 7,995,045, titled COMBINED SBI AND CONVENTIONAL IMAGE PROCESSOR, which issued on Aug. 9, 2011, which is herein incorporated by reference in its entirety. In addition, U.S. Pat. No. 7,982,776, titled SBI MOTION ARTIFACT REMOVAL APPARATUS AND METHOD, which issued on Jul. 19, 2011, which is herein incorporated by reference in its entirety, describes various systems for removing motion artifacts from image data. Such systems can be integrated with the imaging module **138**. Furthermore, U.S. Patent Application Publication No. 2011/0306840, titled CONTROLLABLE MAGNETIC SOURCE TO FIXTURE INTRACORPOREAL APPARATUS, which published on Dec. 15, 2011, and U.S. Patent Application Publication No. 2014/0243597, titled SYSTEM FOR PERFORMING A MINIMALLY INVASIVE SURGICAL PROCEDURE, which published on Aug. 28, 2014, now

U.S. Pat. No. 10,098,527, each of which is herein incorporated by reference in its entirety.

[0231] FIG. **8** illustrates a surgical data network **201** comprising a modular communication hub **203** configured to connect modular devices located in one or more operating theaters of a healthcare facility, or any room in a healthcare facility specially equipped for surgical operations, to a cloud-based system (e.g., the cloud **204** that may include a remote server **213** coupled to a storage device **205**). In one aspect, the modular communication hub **203** comprises a network hub **207** and/or a network switch **209** in communication with a network router. The modular communication hub **203** also can be coupled to a local computer system **210** to provide local computer processing and data manipulation. The surgical data network **201** may be configured as passive, intelligent, or switching. A passive surgical data network serves as a conduit for the data, enabling it to go from one device (or segment) to another and to the cloud computing resources. An intelligent surgical data network includes additional features to enable the traffic passing through the surgical data network to be monitored and to configure each port in the network hub **207** or network switch **209**. An intelligent surgical data network may be referred to as a manageable hub or switch. A switching hub reads the destination address of each packet and then forwards the packet to the correct port.

[0232] Modular devices **1a-1n** located in the operating theater may be coupled to the modular communication hub **203**. The network hub **207** and/or the network switch **209** may be coupled to a network router **211** to connect the devices **1a-1n** to the cloud **204** or the local computer system **210**. Data associated with the devices **1a-1n** may be transferred to cloud-based computers via the router for remote data processing and manipulation. Data associated with the devices **1a-1n** may also be transferred to the local computer system **210** for local data processing and manipulation. Modular devices **2a-2m** located in the same operating theater also may be coupled to a network switch **209**. The network switch **209** may be coupled to the network hub **207** and/or the network router **211** to connect to the devices **2a-2m** to the cloud **204**. Data associated with the devices **2a-2n** may be transferred to the cloud **204** via the network router **211** for data processing and manipulation. Data associated with the devices **2a-2m** may also be transferred to the local computer system **210** for local data processing and manipulation.

[0233] It will be appreciated that the surgical data network **201** may be expanded by interconnecting multiple network hubs **207** and/or multiple network switches **209** with multiple network routers **211**. The modular communication hub **203** may be contained in a modular control tower configured to receive multiple devices **1a-1n/2a-2m**. The local computer system **210** also may be contained in a modular control tower. The modular communication hub **203** is connected to a display **212** to display images obtained by some of the devices **1a-1n/2a-2m**, for example during surgical procedures. In various aspects, the devices **1a-1n/2a-2m** may include, for example, various modules such as an imaging module **138** coupled to an endoscope, a generator module **140** coupled to an energy-based surgical device, a smoke evacuation module **126**, a suction/irrigation module **128**, a communication module **130**, a processor module **132**, a storage array **134**, a surgical device coupled to a display, and/or a non-contact sensor module, among other modular devices that may be connected to the modular communication hub **203** of the surgical data network **201**.

[0234] In one aspect, the surgical data network **201** may comprise a combination of network hub(s), network switch(es), and network router(s) connecting the devices **1a-1n/2a-2m** to the cloud. Any one of or all of the devices **1a-1n/2a-2m** coupled to the network hub or network switch may collect data in real time and transfer the data to cloud computers for data processing and manipulation. It will be appreciated that cloud computing relies on sharing computing resources rather than having local servers or personal devices to handle software applications. The word "cloud" may be used as a metaphor for "the Internet," although the term is not limited as such. Accordingly, the term "cloud computing" may be used herein to refer to "a type of Internet-based computing," where different services—such as servers, storage, and applications—are delivered to the modular communication hub **203** and/or computer system **210** located in the surgical theater (e.g., a fixed, mobile, temporary, or field operating room or space) and to devices connected to the

modular communication hub **203** and/or computer system **210** through the Internet. The cloud infrastructure may be maintained by a cloud service provider. In this context, the cloud service provider may be the entity that coordinates the usage and control of the devices **1***a*-**1***n*/**2***a*-**2***m* located in one or more operating theaters. The cloud computing services can perform a large number of calculations based on the data gathered by smart surgical instruments, robots, and other computerized devices located in the operating theater. The hub hardware enables multiple devices or connections to be connected to a computer that communicates with the cloud computing resources and storage.

[0235] Applying cloud computer data processing techniques on the data collected by the devices **1***a*-**1***n*/**2***a*-**2***m*, the surgical data network provides improved surgical outcomes, reduced costs, and improved patient satisfaction. At least some of the devices **1***a*-**1***n*/**2***a*-**2***m* may be employed to view tissue states to assess leaks or perfusion of sealed tissue after a tissue sealing and cutting procedure. At least some of the devices **1***a*-**1***n*/**2***a*-**2***m* may be employed to identify pathology, such as the effects of diseases, using the cloud-based computing to examine data including images of samples of body tissue for diagnostic purposes. This includes localization and margin confirmation of tissue and phenotypes. At least some of the devices **1***a*-**1***n*/**2***a*-**2***m* may be employed to identify anatomical structures of the body using a variety of sensors integrated with imaging devices and techniques such as overlaying images captured by multiple imaging devices. The data gathered by the devices **1***a*-**1***n*/**2***a*-**2***m*, including image data, may be transferred to the cloud **204** or the local computer system **210** or both for data processing and manipulation including image processing and manipulation. The data may be analyzed to improve surgical procedure outcomes by determining if further treatment, such as the application of endoscopic intervention, emerging technologies, a targeted radiation, targeted intervention, and precise robotics to tissue-specific sites and conditions, may be pursued. Such data analysis may further employ outcome analytics processing, and using standardized approaches may provide beneficial feedback to either confirm surgical treatments and the behavior of the surgeon or suggest modifications to surgical treatments and the behavior of the surgeon.

[0236] In one implementation, the operating theater devices **1***a*-**1***n* may be connected to the modular communication hub **203** over a wired channel or a wireless channel depending on the configuration of the devices **1***a*-**1***n* to a network hub. The network hub **207** may be implemented, in one aspect, as a local network broadcast device that works on the physical layer of the Open System Interconnection (OSI) model. The network hub provides connectivity to the devices **1***a*-**1***n* located in the same operating theater network. The network hub **207** collects data in the form of packets and sends them to the router in half duplex mode. The network hub **207** does not store any media access control/Internet Protocol (MAC/IP) to transfer the device data. Only one of the devices **1***a*-**1***n* can send data at a time through the network hub **207**. The network hub **207** has no routing tables or intelligence regarding where to send information and broadcasts all network data across each connection and to a remote server **213** (FIG. **9**) over the cloud **204**. The network hub **207** can detect basic network errors such as collisions, but having all information broadcast to multiple ports can be a security risk and cause bottlenecks.

[0237] In another implementation, the operating theater devices **2***a*-**2***m* may be connected to a network switch **209** over a wired channel or a wireless channel. The network switch **209** works in the data link layer of the OSI model. The network switch **209** is a multicast device for connecting the devices **2***a*-**2***m* located in the same operating theater to the network. The network switch **209** sends data in the form of frames to the network router **211** and works in full duplex mode. Multiple devices **2***a*-**2***m* can send data at the same time through the network switch **209**. The network switch **209** stores and uses MAC addresses of the devices **2***a*-**2***m* to transfer data.

[0238] The network hub **207** and/or the network switch **209** are coupled to the network router **211** for connection to the cloud **204**. The network router **211** works in the network layer of the OSI model. The network router **211** creates a route for transmitting data packets received from the

network hub **207** and/or network switch **211** to cloud-based computer resources for further processing and manipulation of the data collected by any one of or all the devices **1***a*-**1***n*/**2***a*-**2***m*. The network router **211** may be employed to connect two or more different networks located in different locations, such as, for example, different operating theaters of the same healthcare facility or different networks located in different operating theaters of different healthcare facilities. The network router **211** sends data in the form of packets to the cloud **204** and works in full duplex mode. Multiple devices can send data at the same time. The network router **211** uses IP addresses to transfer data.

[0239] In one example, the network hub **207** may be implemented as a USB hub, which allows multiple USB devices to be connected to a host computer. The USB hub may expand a single USB port into several tiers so that there are more ports available to connect devices to the host system computer. The network hub **207** may include wired or wireless capabilities to receive information over a wired channel or a wireless channel. In one aspect, a wireless USB short-range, high-bandwidth wireless radio communication protocol may be employed for communication between the devices **1***a*-**1***n* and devices **2***a*-**2***m* located in the operating theater.

[0240] In other examples, the operating theater devices **1***a*-**1***n*/**2***a*-**2***m* may communicate to the modular communication hub **203** via Bluetooth wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHZ) from fixed and mobile devices and building personal area networks (PANs). In other aspects, the operating theater devices **1***a*-**1***n*/**2***a*-**2***m* may communicate to the modular communication hub **203** via a number of wireless or wired communication standards or protocols, including but not limited to Wi-Fi (IEEE 802.11 family), WiMAX (IEEE 802.16 family), IEEE 802.20, long-term evolution (LTE), and Ev-DO, HSPA+, HSDPA+, HSUPA+, EDGE, GSM, GPRS, CDMA, TDMA, DECT, and Ethernet derivatives thereof, as well as any other wireless and wired protocols that are designated as 3G, 4G, 5G, and beyond. The computing module may include a plurality of communication modules. For instance, a first communication module may be dedicated to shorter-range wireless communications such as Wi-Fi and Bluetooth, and a second communication module may be dedicated to longer-range wireless communications such as GPS, EDGE, GPRS, CDMA, WiMAX, LTE, Ev-DO, and others.

[0241] The modular communication hub **203** may serve as a central connection for one or all of the operating theater devices **1***a*-**1***n*/**2***a*-**2***m* and handles a data type known as frames. Frames carry the data generated by the devices **1***a*-**1***n*/**2***a*-**2***m*. When a frame is received by the modular communication hub **203**, it is amplified and transmitted to the network router **211**, which transfers the data to the cloud computing resources by using a number of wireless or wired communication standards or protocols, as described herein.

[0242] The modular communication hub **203** can be used as a standalone device or be connected to compatible network hubs and network switches to form a larger network. The modular communication hub **203** is generally easy to install, configure, and maintain, making it a good option for networking the operating theater devices **1***a*-**1***n*/**2***a*-**2***m.*

[0243] FIG. **9** illustrates a computer-implemented interactive surgical system **200**. The computer-implemented interactive surgical system **200** is similar in many respects to the computer-implemented interactive surgical system **100**. For example, the computer-implemented interactive surgical system **200** includes one or more surgical systems **202**, which are similar in many respects to the surgical systems **102**. Each surgical system **202** includes at least one surgical hub **206** in communication with a cloud **204** that may include a remote server **213**. In one aspect, the computer-implemented interactive surgical system **200** comprises a modular control tower **236** connected to multiple operating theater devices such as, for example, intelligent surgical instruments, robots, and other computerized devices located in the operating theater. As shown in FIG. **10**, the modular control tower **236** comprises a modular communication hub **203** coupled to a computer system **210**. As illustrated in the example of FIG. **9**, the modular control tower **236** is

coupled to an imaging module **238** that is coupled to an endoscope **239**, a generator module **240** that is coupled to an energy device **241**, a smoke evacuator module **226**, a suction/irrigation module **228**, a communication module **230**, a processor module **232**, a storage array **234**, a smart device/instrument **235** optionally coupled to a display **237**, and a non-contact sensor module **242**. The operating theater devices are coupled to cloud computing resources and data storage via the modular control tower **236**. A robot hub **222** also may be connected to the modular control tower **236** and to the cloud computing resources. The devices/instruments **235**, visualization systems **208**, among others, may be coupled to the modular control tower **236** via wired or wireless communication standards or protocols, as described herein. The modular control tower **236** may be coupled to a hub display **215** (e.g., monitor, screen) to display and overlay images received from the imaging module, device/instrument display, and/or other visualization systems **208**. The hub display also may display data received from devices connected to the modular control tower in conjunction with images and overlaid images.

[0244] FIG. **10** illustrates a surgical hub **206** comprising a plurality of modules coupled to the modular control tower **236**. The modular control tower **236** comprises a modular communication hub **203**, e.g., a network connectivity device, and a computer system **210** to provide local processing, visualization, and imaging, for example. As shown in FIG. **10**, the modular communication hub **203** may be connected in a tiered configuration to expand the number of modules (e.g., devices) that may be connected to the modular communication hub **203** and transfer data associated with the modules to the computer system **210**, cloud computing resources, or both. As shown in FIG. **10**, each of the network hubs/switches in the modular communication hub **203** includes three downstream ports and one upstream port. The upstream network hub/switch is connected to a processor to provide a communication connection to the cloud computing resources and a local display **217**. Communication to the cloud **204** may be made either through a wired or a wireless communication channel.

[0245] The surgical hub **206** employs a non-contact sensor module **242** to measure the dimensions of the operating theater and generate a map of the surgical theater using either ultrasonic or laser-type non-contact measurement devices. An ultrasound-based non-contact sensor module scans the operating theater by transmitting a burst of ultrasound and receiving the echo when it bounces off the perimeter walls of an operating theater as described under the heading "Surgical Hub Spatial Awareness Within an Operating Room" in U.S. Provisional Patent Application Ser. No. 62/611,341, titled INTERACTIVE SURGICAL PLATFORM, filed Dec. 28, 2017, which is herein incorporated by reference in its entirety, in which the sensor module is configured to determine the size of the operating theater and to adjust Bluetooth-pairing distance limits. A laser-based non-contact sensor module scans the operating theater by transmitting laser light pulses, receiving laser light pulses that bounce off the perimeter walls of the operating theater, and comparing the phase of the transmitted pulse to the received pulse to determine the size of the operating theater and to adjust Bluetooth pairing distance limits, for example.

[0246] The computer system **210** comprises a processor **244** and a network interface **245**. The processor **244** is coupled to a communication module **247**, storage **248**, memory **249**, non-volatile memory **250**, and input/output interface **251** via a system bus. The system bus can be any of several types of bus structure(s) including the memory bus or memory controller, a peripheral bus or external bus, and/or a local bus using any variety of available bus architectures including, but not limited to, 9-bit bus, Industrial Standard Architecture (ISA), Micro-Charmel Architecture (MSA), Extended ISA (EISA), Intelligent Drive Electronics (IDE), VESA Local Bus (VLB), Peripheral Component Interconnect (PCI), USB, Advanced Graphics Port (AGP), Personal Computer Memory Card International Association bus (PCMCIA), Small Computer Systems Interface (SCSI), or any other proprietary bus.

[0247] The processor **244** may be any single-core or multicore processor such as those known under the trade name ARM Cortex by Texas Instruments. In one aspect, the processor may be an

LM4F230H5QR ARM Cortex-M4F Processor Core, available from Texas Instruments, for example, comprising an on-chip memory of 256 KB single-cycle flash memory, or other non-volatile memory, up to 40 MHZ, a prefetch buffer to improve performance above 40 MHz, a 32 KB single-cycle serial random access memory (SRAM), an internal read-only memory (ROM) loaded with StellarisWare® software, a 2 KB electrically erasable programmable read-only memory (EEPROM), and/or one or more pulse width modulation (PWM) modules, one or more quadrature encoder inputs (QEI) analogs, one or more 12-bit analog-to-digital converters (ADCs) with 12 analog input channels, details of which are available for the product datasheet.

[0248] In one aspect, the processor **244** may comprise a safety controller comprising two controller-based families such as TMS570 and RM4x, known under the trade name Hercules ARM Cortex R4, also by Texas Instruments. The safety controller may be configured specifically for IEC 61508 and ISO 26262 safety critical applications, among others, to provide advanced integrated safety features while delivering scalable performance, connectivity, and memory options.

[0249] The system memory includes volatile memory and non-volatile memory. The basic input/output system (BIOS), containing the basic routines to transfer information between elements within the computer system, such as during start-up, is stored in non-volatile memory. For example, the non-volatile memory can include ROM, programmable ROM (PROM), electrically programmable ROM (EPROM), EEPROM, or flash memory. Volatile memory includes random-access memory (RAM), which acts as external cache memory. Moreover, RAM is available in many forms such as SRAM, dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM).

[0250] The computer system **210** also includes removable/non-removable, volatile/non-volatile computer storage media, such as for example disk storage. The disk storage includes, but is not limited to, devices like a magnetic disk drive, floppy disk drive, tape drive, Jaz drive, Zip drive, LS-60 drive, flash memory card, or memory stick. In addition, the disk storage can include storage media separately or in combination with other storage media including, but not limited to, an optical disc drive such as a compact disc ROM device (CD-ROM), compact disc recordable drive (CD-R Drive), compact disc rewritable drive (CD-RW Drive), or a digital versatile disc ROM drive (DVD-ROM). To facilitate the connection of the disk storage devices to the system bus, a removable or non-removable interface may be employed.

[0251] It is to be appreciated that the computer system **210** includes software that acts as an intermediary between users and the basic computer resources described in a suitable operating environment. Such software includes an operating system. The operating system, which can be stored on the disk storage, acts to control and allocate resources of the computer system. System applications take advantage of the management of resources by the operating system through program modules and program data stored either in the system memory or on the disk storage. It is to be appreciated that various components described herein can be implemented with various operating systems or combinations of operating systems.

[0252] A user enters commands or information into the computer system **210** through input device(s) coupled to the I/O interface **251**. The input devices include, but are not limited to, a pointing device such as a mouse, trackball, stylus, touch pad, keyboard, microphone, joystick, game pad, satellite dish, scanner, TV tuner card, digital camera, digital video camera, web camera, and the like. These and other input devices connect to the processor through the system bus via interface port(s). The interface port(s) include, for example, a serial port, a parallel port, a game port, and a USB. The output device(s) use some of the same types of ports as input device(s). Thus, for example, a USB port may be used to provide input to the computer system and to output information from the computer system to an output device. An output adapter is provided to illustrate that there are some output devices like monitors, displays, speakers, and printers, among other output devices that require special adapters. The output adapters include, by way of

illustration and not limitation, video and sound cards that provide a means of connection between the output device and the system bus. It should be noted that other devices and/or systems of devices, such as remote computer(s), provide both input and output capabilities.

[0253] The computer system **210** can operate in a networked environment using logical connections to one or more remote computers, such as cloud computer(s), or local computers. The remote cloud computer(s) can be a personal computer, server, router, network PC, workstation, microprocessor-based appliance, peer device, or other common network node, and the like, and typically includes many or all of the elements described relative to the computer system. For purposes of brevity, only a memory storage device is illustrated with the remote computer(s). The remote computer(s) is logically connected to the computer system through a network interface and then physically connected via a communication connection. The network interface encompasses communication networks such as local area networks (LANs) and wide area networks (WANs). LAN technologies include Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), Ethernet/IEEE 802.3, Token Ring/IEEE 802.5 and the like. WAN technologies include, but are not limited to, point-to-point links, circuit-switching networks like Integrated Services Digital Networks (ISDN) and variations thereon, packet-switching networks, and Digital Subscriber Lines (DSL).

[0254] In various aspects, the computer system **210** of FIG. **10**, the imaging module **238** and/or visualization system **208**, and/or the processor module **232** of FIGS. **9**-**10**, may comprise an image processor, image-processing engine, media processor, or any specialized digital signal processor (DSP) used for the processing of digital images. The image processor may employ parallel computing with single instruction, multiple data (SIMD) or multiple instruction, multiple data (MIMD) technologies to increase speed and efficiency. The digital image-processing engine can perform a range of tasks. The image processor may be a system on a chip with multicore processor architecture.

[0255] The communication connection(s) refers to the hardware/software employed to connect the network interface to the bus. While the communication connection is shown for illustrative clarity inside the computer system, it can also be external to the computer system **210**. The hardware/software necessary for connection to the network interface includes, for illustrative purposes only, internal and external technologies such as modems, including regular telephone-grade modems, cable modems, and DSL modems, ISDN adapters, and Ethernet cards.

[0256] FIG. **11** illustrates a functional block diagram of one aspect of a USB network hub **300** device, in accordance with at least one aspect of the present disclosure. In the illustrated aspect, the USB network hub device **300** employs a TUSB2036 integrated circuit hub by Texas Instruments. The USB network hub **300** is a CMOS device that provides an upstream USB transceiver port **302** and up to three downstream USB transceiver ports **304**, **306**, **308** in compliance with the USB 2.0 specification. The upstream USB transceiver port **302** is a differential root data port comprising a differential data minus (DM0) input paired with a differential data plus (DP0) input. The three downstream USB transceiver ports **304**, **306**, **308** are differential data ports where each port includes differential data plus (DP1-DP3) outputs paired with differential data minus (DM1-DM3) outputs.

[0257] The USB network hub **300** device is implemented with a digital state machine instead of a microcontroller, and no firmware programming is required. Fully compliant USB transceivers are integrated into the circuit for the upstream USB transceiver port **302** and all downstream USB transceiver ports **304**, **306**, **308**. The downstream USB transceiver ports **304**, **306**, **308** support both full-speed and low-speed devices by automatically setting the slew rate according to the speed of the device attached to the ports. The USB network hub **300** device may be configured either in bus-powered or self-powered mode and includes a hub power logic **312** to manage power.

[0258] The USB network hub **300** device includes a serial interface engine **310** (SIE). The SIE **310** is the front end of the USB network hub **300** hardware and handles most of the protocol described

in chapter 8 of the USB specification. The SIE **310** typically comprehends signaling up to the transaction level. The functions that it handles could include: packet recognition, transaction sequencing, SOP, EOP, RESET, and RESUME signal detection/generation, clock/data separation, non-return-to-zero invert (NRZI) data encoding/decoding and bit-stuffing, CRC generation and checking (token and data), packet ID (PID) generation and checking/decoding, and/or serial-parallel/parallel-serial conversion. The **310** receives a clock input **314** and is coupled to a suspend/resume logic and frame timer **316** circuit and a hub repeater circuit **318** to control communication between the upstream USB transceiver port **302** and the downstream USB transceiver ports **304**, **306**, **308** through port logic circuits **320**, **322**, **324**. The SIE **310** is coupled to a command decoder **326** via interface logic **328** to control commands from a serial EEPROM via a serial EEPROM interface **330**.

[0259] In various aspects, the USB network hub **300** can connect **127** functions configured in up to six logical layers (tiers) to a single computer. Further, the USB network hub **300** can connect to all peripherals using a standardized four-wire cable that provides both communication and power distribution. The power configurations are bus-powered and self-powered modes. The USB network hub **300** may be configured to support four modes of power management: a bus-powered hub, with either individual-port power management or ganged-port power management, and the self-powered hub, with either individual-port power management or ganged-port power management. In one aspect, using a USB cable, the USB network hub **300**, the upstream USB transceiver port **302** is plugged into a USB host controller, and the downstream USB transceiver ports **304**, **306**, **308** are exposed for connecting USB compatible devices, and so forth.

[0260] Additional details regarding the structure and function of the surgical hub and/or surgical hub networks can be found in U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is hereby incorporated by reference herein in its entirety.

Cloud System Hardware and Functional Modules

[0261] FIG. **12** is a block diagram of the computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure. In one aspect, the computer-implemented interactive surgical system is configured to monitor and analyze data related to the operation of various surgical systems that include surgical hubs, surgical instruments, robotic devices and operating theaters or healthcare facilities. The computer-implemented interactive surgical system comprises a cloud-based analytics system. Although the cloud-based analytics system is described as a surgical system, it is not necessarily limited as such and could be a cloud-based medical system generally. As illustrated in FIG. **12**, the cloud-based analytics system comprises a plurality of surgical instruments **7012** (may be the same or similar to instruments **112**), a plurality of surgical hubs **7006** (may be the same or similar to hubs **106**), and a surgical data network **7001** (may be the same or similar to network **201**) to couple the surgical hubs **7006** to the cloud **7004** (may be the same or similar to cloud **204**). Each of the plurality of surgical hubs **7006** is communicatively coupled to one or more surgical instruments **7012**. The hubs **7006** are also communicatively coupled to the cloud **7004** of the computer-implemented interactive surgical system via the network **7001**. The cloud **7004** is a remote centralized source of hardware and software for storing, manipulating, and communicating data generated based on the operation of various surgical systems. As shown in FIG. **12**, access to the cloud **7004** is achieved via the network **7001**, which may be the Internet or some other suitable computer network. Surgical hubs **7006** that are coupled to the cloud **7004** can be considered the client side of the cloud computing system (i.e., cloud-based analytics system). Surgical instruments **7012** are paired with the surgical hubs **7006** for control and implementation of various surgical procedures or operations as described herein.

[0262] In addition, surgical instruments **7012** may comprise transceivers for data transmission to and from their corresponding surgical hubs **7006** (which may also comprise transceivers).

Combinations of surgical instruments **7012** and corresponding hubs **7006** may indicate particular locations, such as operating theaters in healthcare facilities (e.g., hospitals), for providing medical operations. For example, the memory of a surgical hub **7006** may store location data. As shown in FIG. **12**, the cloud **7004** comprises central servers **7013** (which may be same or similar to remote server **113** in FIG. **1** and/or remote server **213** in FIG. **9**), hub application servers **7002**, data analytics modules **7034**, and an input/output ("I/O") interface **7007**. The central servers **7013** of the cloud **7004** collectively administer the cloud computing system, which includes monitoring requests by client surgical hubs **7006** and managing the processing capacity of the cloud **7004** for executing the requests. Each of the central servers **7013** comprises one or more processors **7008** coupled to suitable memory devices **7010** which can include volatile memory such as random-access memory (RAM) and non-volatile memory such as magnetic storage devices. The memory devices **7010** may comprise machine executable instructions that when executed cause the processors **7008** to execute the data analytics modules **7034** for the cloud-based data analysis, operations, recommendations and other operations described below. Moreover, the processors **7008** can execute the data analytics modules **7034** independently or in conjunction with hub applications independently executed by the hubs **7006**. The central servers **7013** also comprise aggregated medical data databases **2212**, which can reside in the memory **2210**.

[0263] Based on connections to various surgical hubs **7006** via the network **7001**, the cloud **7004** can aggregate data from specific data generated by various surgical instruments **7012** and their corresponding hubs **7006**. Such aggregated data may be stored within the aggregated medical data databases **7011** of the cloud **7004**. In particular, the cloud **7004** may advantageously perform data analysis and operations on the aggregated data to yield insights and/or perform functions that individual hubs **7006** could not achieve on their own. To this end, as shown in FIG. **12**, the cloud **7004** and the surgical hubs **7006** are communicatively coupled to transmit and receive information. The I/O interface **7007** is connected to the plurality of surgical hubs **7006** via the network **7001**. In this way, the I/O interface **7007** can be configured to transfer information between the surgical hubs **7006** and the aggregated medical data databases **7011**. Accordingly, the I/O interface **7007** may facilitate read/write operations of the cloud-based analytics system. Such read/write operations may be executed in response to requests from hubs **7006**. These requests could be transmitted to the hubs **7006** through the hub applications. The I/O interface **7007** may include one or more high speed data ports, which may include universal serial bus (USB) ports, IEEE 1394 ports, as well as Wi-Fi and Bluetooth I/O interfaces for connecting the cloud **7004** to hubs **7006**. The hub application servers **7002** of the cloud **7004** are configured to host and supply shared capabilities to software applications (e.g. hub applications) executed by surgical hubs **7006**. For example, the hub application servers **7002** may manage requests made by the hub applications through the hubs **7006**, control access to the aggregated medical data databases **7011**, and perform load balancing. The data analytics modules **7034** are described in further detail with reference to FIG. **13**.

[0264] The particular cloud computing system configuration described in the present disclosure is specifically designed to address various issues arising in the context of medical operations and procedures performed using medical devices, such as the surgical instruments **7012**, **112**. In particular, the surgical instruments **7012** may be digital surgical devices configured to interact with the cloud **7004** for implementing techniques to improve the performance of surgical operations. Various surgical instruments **7012** and/or surgical hubs **7006** may comprise touch controlled user interfaces such that clinicians may control aspects of interaction between the surgical instruments **7012** and the cloud **7004**. Other suitable user interfaces for control such as auditory controlled user interfaces can also be used.

[0265] FIG. **13** is a block diagram which illustrates the functional architecture of the computer-implemented interactive surgical system, in accordance with at least one aspect of the present disclosure. The cloud-based analytics system includes a plurality of data analytics modules **7034** that may be executed by the processors **7008** of the cloud **7004** for providing data analytic

solutions to problems specifically arising in the medical field. As shown in FIG. **13**, the functions of the cloud-based data analytics modules **7034** may be assisted via hub applications **7014** hosted by the hub application servers **7002** that may be accessed on surgical hubs **7006**. The cloud processors **7008** and hub applications **7014** may operate in conjunction to execute the data analytics modules **7034**. Application program interfaces (APIs) **7016** define the set of protocols and routines corresponding to the hub applications **7014**. Additionally, the APIs **7016** manage the storing and retrieval of data into and from the aggregated medical data databases **7011** for the operations of the applications **7014**. The caches **7018** also store data (e.g., temporarily) and are coupled to the APIs **7016** for more efficient retrieval of data used by the applications **7014**. The data analytics modules **7034** in FIG. **13** include modules for resource optimization **7020**, data collection and aggregation **7022**, authorization and security **7024**, control program updating **7026**, patient outcome analysis **7028**, recommendations **7030**, and data sorting and prioritization **7032**. Other suitable data analytics modules could also be implemented by the cloud **7004**, according to some aspects. In one aspect, the data analytics modules are used for specific recommendations based on analyzing trends, outcomes, and other data.

[0266] For example, the data collection and aggregation module **7022** could be used to generate self-describing data (e.g., metadata) including identification of notable features or configuration (e.g., trends), management of redundant data sets, and storage of the data in paired data sets which can be grouped by surgery but not necessarily keyed to actual surgical dates and surgeons. In particular, pair data sets generated from operations of surgical instruments **7012** can comprise applying a binary classification, e.g., a bleeding or a non-bleeding event. More generally, the binary classification may be characterized as either a desirable event (e.g., a successful surgical procedure) or an undesirable event (e.g., a misfired or misused surgical instrument **7012**). The aggregated self-describing data may correspond to individual data received from various groups or subgroups of surgical hubs **7006**. Accordingly, the data collection and aggregation module **7022** can generate aggregated metadata or other organized data based on raw data received from the surgical hubs **7006**. To this end, the processors **7008** can be operationally coupled to the hub applications **7014** and aggregated medical data databases **7011** for executing the data analytics modules **7034**. The data collection and aggregation module **7022** may store the aggregated organized data into the aggregated medical data databases **2212**.

[0267] The resource optimization module **7020** can be configured to analyze this aggregated data to determine an optimal usage of resources for a particular or group of healthcare facilities. For example, the resource optimization module **7020** may determine an optimal order point of surgical stapling instruments **7012** for a group of healthcare facilities based on corresponding predicted demand of such instruments **7012**. The resource optimization module **7020** might also assess the resource usage or other operational configurations of various healthcare facilities to determine whether resource usage could be improved. Similarly, the recommendations module **7030** can be configured to analyze aggregated organized data from the data collection and aggregation module **7022** to provide recommendations. For example, the recommendations module **7030** could recommend to healthcare facilities (e.g., medical service providers such as hospitals) that a particular surgical instrument **7012** should be upgraded to an improved version based on a higher than expected error rate, for example. Additionally, the recommendations module **7030** and/or resource optimization module **7020** could recommend better supply chain parameters such as product reorder points and provide suggestions of different surgical instrument **7012**, uses thereof, or procedure steps to improve surgical outcomes. The healthcare facilities can receive such recommendations via corresponding surgical hubs **7006**. More specific recommendations regarding parameters or configurations of various surgical instruments **7012** can also be provided. Hubs **7006** and/or surgical instruments **7012** each could also have display screens that display data or recommendations provided by the cloud **7004**.

[0268] The patient outcome analysis module **7028** can analyze surgical outcomes associated with

currently used operational parameters of surgical instruments **7012**. The patient outcome analysis module **7028** may also analyze and assess other potential operational parameters. In this connection, the recommendations module **7030** could recommend using these other potential operational parameters based on yielding better surgical outcomes, such as better sealing or less bleeding. For example, the recommendations module **7030** could transmit recommendations to a surgical hub **7006** regarding when to use a particular cartridge for a corresponding stapling surgical instrument **7012**. Thus, the cloud-based analytics system, while controlling for common variables, may be configured to analyze the large collection of raw data and to provide centralized recommendations over multiple healthcare facilities (advantageously determined based on aggregated data). For example, the cloud-based analytics system could analyze, evaluate, and/or aggregate data based on type of medical practice, type of patient, number of patients, geographic similarity between medical providers, which medical providers/facilities use similar types of instruments, etc., in a way that no single healthcare facility alone would be able to analyze independently.

[0269] The control program updating module **7026** could be configured to implement various surgical instrument **7012** recommendations when corresponding control programs are updated. For example, the patient outcome analysis module **7028** could identify correlations linking specific control parameters with successful (or unsuccessful) results. Such correlations may be addressed when updated control programs are transmitted to surgical instruments **7012** via the control program updating module **7026**. Updates to instruments **7012** that are transmitted via a corresponding hub **7006** may incorporate aggregated performance data that was gathered and analyzed by the data collection and aggregation module **7022** of the cloud **7004**. Additionally, the patient outcome analysis module **7028** and recommendations module **7030** could identify improved methods of using instruments **7012** based on aggregated performance data.

[0270] The cloud-based analytics system may include security features implemented by the cloud **7004**. These security features may be managed by the authorization and security module **7024**. Each surgical hub **7006** can have associated unique credentials such as username, password, and other suitable security credentials. These credentials could be stored in the memory **7010** and be associated with a permitted cloud access level. For example, based on providing accurate credentials, a surgical hub **7006** may be granted access to communicate with the cloud to a predetermined extent (e.g., may only engage in transmitting or receiving certain defined types of information). To this end, the aggregated medical data databases **7011** of the cloud **7004** may comprise a database of authorized credentials for verifying the accuracy of provided credentials. Different credentials may be associated with varying levels of permission for interaction with the cloud **7004**, such as a predetermined access level for receiving the data analytics generated by the cloud **7004**.

[0271] Furthermore, for security purposes, the cloud could maintain a database of hubs **7006**, instruments **7012**, and other devices that may comprise a "black list" of prohibited devices. In particular, a surgical hub **7006** listed on the black list may not be permitted to interact with the cloud, while surgical instruments **7012** listed on the black list may not have functional access to a corresponding hub **7006** and/or may be prevented from fully functioning when paired to its corresponding hub **7006**. Additionally or alternatively, the cloud **7004** may flag instruments **7012** based on incompatibility or other specified criteria. In this manner, counterfeit medical devices and improper reuse of such devices throughout the cloud-based analytics system can be identified and addressed.

[0272] The surgical instruments **7012** may use wireless transceivers to transmit wireless signals that may represent, for example, authorization credentials for access to corresponding hubs **7006** and the cloud **7004**. Wired transceivers may also be used to transmit signals. Such authorization credentials can be stored in the respective memory devices of the surgical instruments **7012**. The authorization and security module **7024** can determine whether the authorization credentials are

accurate or counterfeit. The authorization and security module **7024** may also dynamically generate authorization credentials for enhanced security. The credentials could also be encrypted, such as by using hash based encryption. Upon transmitting proper authorization, the surgical instruments **7012** may transmit a signal to the corresponding hubs **7006** and ultimately the cloud **7004** to indicate that the instruments **7012** are ready to obtain and transmit medical data. In response, the cloud **7004** may transition into a state enabled for receiving medical data for storage into the aggregated medical data databases **7011**. This data transmission readiness could be indicated by a light indicator on the instruments **7012**, for example. The cloud **7004** can also transmit signals to surgical instruments **7012** for updating their associated control programs. The cloud **7004** can transmit signals that are directed to a particular class of surgical instruments **7012** (e.g., electrosurgical instruments) so that software updates to control programs are only transmitted to the appropriate surgical instruments **7012**. Moreover, the cloud **7004** could be used to implement system wide solutions to address local or global problems based on selective data transmission and authorization credentials. For example, if a group of surgical instruments **7012** are identified as having a common manufacturing defect, the cloud **7004** may change the authorization credentials corresponding to this group to implement an operational lockout of the group.

[0273] The cloud-based analytics system may allow for monitoring multiple healthcare facilities (e.g., medical facilities like hospitals) to determine improved practices and recommend changes (via the recommendations module **2030**, for example) accordingly. Thus, the processors **7008** of the cloud **7004** can analyze data associated with an individual healthcare facility to identify the facility and aggregate the data with other data associated with other healthcare facilities in a group. Groups could be defined based on similar operating practices or geographical location, for example. In this way, the cloud **7004** may provide healthcare facility group wide analysis and recommendations. The cloud-based analytics system could also be used for enhanced situational awareness. For example, the processors **7008** may predictively model the effects of recommendations on the cost and effectiveness for a particular facility (relative to overall operations and/or various medical procedures). The cost and effectiveness associated with that particular facility can also be compared to a corresponding local region of other facilities or any other comparable facilities.

[0274] The data sorting and prioritization module **7032** may prioritize and sort data based on criticality (e.g., the severity of a medical event associated with the data, unexpectedness, suspiciousness). This sorting and prioritization may be used in conjunction with the functions of the other data analytics modules **7034** described above to improve the cloud-based analytics and operations described herein. For example, the data sorting and prioritization module **7032** can assign a priority to the data analysis performed by the data collection and aggregation module **7022** and patient outcome analysis modules **7028**. Different prioritization levels can result in particular responses from the cloud **7004** (corresponding to a level of urgency) such as escalation for an expedited response, special processing, exclusion from the aggregated medical data databases **7011**, or other suitable responses. Moreover, if necessary, the cloud **7004** can transmit a request (e.g. a push message) through the hub application servers for additional data from corresponding surgical instruments **7012**. The push message can result in a notification displayed on the corresponding hubs **7006** for requesting supporting or additional data. This push message may be required in situations in which the cloud detects a significant irregularity or outlier and the cloud cannot determine the cause of the irregularity. The central servers **7013** may be programmed to trigger this push message in certain significant circumstances, such as when data is determined to be different from an expected value beyond a predetermined threshold or when it appears security has been comprised, for example.

[0275] Additional details regarding the cloud analysis system can be found in U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is hereby incorporated by reference herein in its entirety.

Situational Awareness

[0276] Although an "intelligent" device including control algorithms that respond to sensed data can be an improvement over a "dumb" device that operates without accounting for sensed data, some sensed data can be incomplete or inconclusive when considered in isolation, i.e., without the context of the type of surgical procedure being performed or the type of tissue that is being operated on. Without knowing the procedural context (e.g., knowing the type of tissue being operated on or the type of procedure being performed), the control algorithm may control the modular device incorrectly or suboptimally given the particular context-free sensed data. For example, the optimal manner for a control algorithm to control a surgical instrument in response to a particular sensed parameter can vary according to the particular tissue type being operated on. This is due to the fact that different tissue types have different properties (e.g., resistance to tearing) and thus respond differently to actions taken by surgical instruments. Therefore, it may be desirable for a surgical instrument to take different actions even when the same measurement for a particular parameter is sensed. As one specific example, the optimal manner in which to control a surgical stapling and cutting instrument in response to the instrument sensing an unexpectedly high force to close its end effector will vary depending upon whether the tissue type is susceptible or resistant to tearing. For tissues that are susceptible to tearing, such as lung tissue, the instrument's control algorithm would optimally ramp down the motor in response to an unexpectedly high force to close to avoid tearing the tissue. For tissues that are resistant to tearing, such as stomach tissue, the instrument's control algorithm would optimally ramp up the motor in response to an unexpectedly high force to close to ensure that the end effector is clamped properly on the tissue. Without knowing whether lung or stomach tissue has been clamped, the control algorithm may make a suboptimal decision.

[0277] One solution utilizes a surgical hub including a system that is configured to derive information about the surgical procedure being performed based on data received from various data sources and then control the paired modular devices accordingly. In other words, the surgical hub is configured to infer information about the surgical procedure from received data and then control the modular devices paired to the surgical hub based upon the inferred context of the surgical procedure. FIG. **14** illustrates a diagram of a situationally aware surgical system **5100**, in accordance with at least one aspect of the present disclosure. In some exemplifications, the data sources **5126** include, for example, the modular devices **5102** (which can include sensors configured to detect parameters associated with the patient and/or the modular device itself), databases **5122** (e.g., an EMR database containing patient records), and patient monitoring devices **5124** (e.g., a blood pressure (BP) monitor and an electrocardiogramonitor).

[0278] A surgical hub **5104**, which may be similar to the hub **106** in many respects, can be configured to derive the contextual information pertaining to the surgical procedure from the data based upon, for example, the particular combination(s) of received data or the particular order in which the data is received from the data sources **5126**. The contextual information inferred from the received data can include, for example, the type of surgical procedure being performed, the particular step of the surgical procedure that the surgeon is performing, the type of tissue being operated on, or the body cavity that is the subject of the procedure. This ability by some aspects of the surgical hub **5104** to derive or infer information related to the surgical procedure from received data can be referred to as "situational awareness." In one exemplification, the surgical hub **5104** can incorporate a situational awareness system, which is the hardware and/or programming associated with the surgical hub **5104** that derives contextual information pertaining to the surgical procedure from the received data.

[0279] The situational awareness system of the surgical hub **5104** can be configured to derive the contextual information from the data received from the data sources **5126** in a variety of different ways. In one exemplification, the situational awareness system includes a pattern recognition system, or machine learning system (e.g., an artificial neural network), that has been trained on training data to correlate various inputs (e.g., data from databases **5122**, patient monitoring devices

5124, and/or modular devices **5102**) to corresponding contextual information regarding a surgical procedure. In other words, a machine learning system can be trained to accurately derive contextual information regarding a surgical procedure from the provided inputs. In another exemplification, the situational awareness system can include a lookup table storing pre-characterized contextual information regarding a surgical procedure in association with one or more inputs (or ranges of inputs) corresponding to the contextual information. In response to a query with one or more inputs, the lookup table can return the corresponding contextual information for the situational awareness system for controlling the modular devices **5102**. In one exemplification, the contextual information received by the situational awareness system of the surgical hub **5104** is associated with a particular control adjustment or set of control adjustments for one or more modular devices **5102**. In another exemplification, the situational awareness system includes a further machine learning system, lookup table, or other such system, which generates or retrieves one or more control adjustments for one or more modular devices **5102** when provided the contextual information as input.

[0280] A surgical hub **5104** incorporating a situational awareness system provides a number of benefits for the surgical system **5100**. One benefit includes improving the interpretation of sensed and collected data, which would in turn improve the processing accuracy and/or the usage of the data during the course of a surgical procedure. To return to a previous example, a situationally aware surgical hub **5104** could determine what type of tissue was being operated on; therefore, when an unexpectedly high force to close the surgical instrument's end effector is detected, the situationally aware surgical hub **5104** could correctly ramp up or ramp down the motor of the surgical instrument for the type of tissue.

[0281] As another example, the type of tissue being operated can affect the adjustments that are made to the compression rate and load thresholds of a surgical stapling and cutting instrument for a particular tissue gap measurement. A situationally aware surgical hub **5104** could infer whether a surgical procedure being performed is a thoracic or an abdominal procedure, allowing the surgical hub **5104** to determine whether the tissue clamped by an end effector of the surgical stapling and cutting instrument is lung (for a thoracic procedure) or stomach (for an abdominal procedure) tissue. The surgical hub **5104** could then adjust the compression rate and load thresholds of the surgical stapling and cutting instrument appropriately for the type of tissue.

[0282] As yet another example, the type of body cavity being operated in during an insufflation procedure can affect the function of a smoke evacuator. A situationally aware surgical hub **5104** could determine whether the surgical site is under pressure (by determining that the surgical procedure is utilizing insufflation) and determine the procedure type. As a procedure type is generally performed in a specific body cavity, the surgical hub **5104** could then control the motor rate of the smoke evacuator appropriately for the body cavity being operated in. Thus, a situationally aware surgical hub **5104** could provide a consistent amount of smoke evacuation for both thoracic and abdominal procedures.

[0283] As yet another example, the type of procedure being performed can affect the optimal energy level for an ultrasonic surgical instrument or radio frequency (RF) electrosurgical instrument to operate at. Arthroscopic procedures, for example, require higher energy levels because the end effector of the ultrasonic surgical instrument or RF electrosurgical instrument is immersed in fluid. A situationally aware surgical hub **5104** could determine whether the surgical procedure is an arthroscopic procedure. The surgical hub **5104** could then adjust the RF power level or the ultrasonic amplitude of the generator (i.e., "energy level") to compensate for the fluid filled environment. Relatedly, the type of tissue being operated on can affect the optimal energy level for an ultrasonic surgical instrument or RF electrosurgical instrument to operate at. A situationally aware surgical hub **5104** could determine what type of surgical procedure is being performed and then customize the energy level for the ultrasonic surgical instrument or RF electrosurgical instrument, respectively, according to the expected tissue profile for the surgical

procedure. Furthermore, a situationally aware surgical hub **5104** can be configured to adjust the energy level for the ultrasonic surgical instrument or RF electrosurgical instrument throughout the course of a surgical procedure, rather than just on a procedure-by-procedure basis. A situationally aware surgical hub **5104** could determine what step of the surgical procedure is being performed or will subsequently be performed and then update the control algorithms for the generator and/or ultrasonic surgical instrument or RF electrosurgical instrument to set the energy level at a value appropriate for the expected tissue type according to the surgical procedure step.

[0284] As yet another example, data can be drawn from additional data sources **5126** to improve the conclusions that the surgical hub **5104** draws from one data source **5126**. A situationally aware surgical hub **5104** could augment data that it receives from the modular devices **5102** with contextual information that it has built up regarding the surgical procedure from other data sources **5126**. For example, a situationally aware surgical hub **5104** can be configured to determine whether hemostasis has occurred (i.e., whether bleeding at a surgical site has stopped) according to video or image data received from a medical imaging device. However, in some cases the video or image data can be inconclusive. Therefore, in one exemplification, the surgical hub **5104** can be further configured to compare a physiologic measurement (e.g., blood pressure sensed by a BP monitor communicably connected to the surgical hub **5104**) with the visual or image data of hemostasis (e.g., from a medical imaging device **124** (FIG. **2**) communicably coupled to the surgical hub **5104**) to make a determination on the integrity of the staple line or tissue weld. In other words, the situational awareness system of the surgical hub **5104** can consider the physiological measurement data to provide additional context in analyzing the visualization data. The additional context can be useful when the visualization data may be inconclusive or incomplete on its own.

[0285] Another benefit includes proactively and automatically controlling the paired modular devices **5102** according to the particular step of the surgical procedure that is being performed to reduce the number of times that medical personnel are required to interact with or control the surgical system **5100** during the course of a surgical procedure. For example, a situationally aware surgical hub **5104** could proactively activate the generator to which an RF electrosurgical instrument is connected if it determines that a subsequent step of the procedure requires the use of the instrument. Proactively activating the energy source allows the instrument to be ready for use a soon as the preceding step of the procedure is completed.

[0286] As another example, a situationally aware surgical hub **5104** could determine whether the current or subsequent step of the surgical procedure requires a different view or degree of magnification on the display according to the feature(s) at the surgical site that the surgeon is expected to need to view. The surgical hub **5104** could then proactively change the displayed view (supplied by, e.g., a medical imaging device for the visualization system **108**) accordingly so that the display automatically adjusts throughout the surgical procedure.

[0287] As yet another example, a situationally aware surgical hub **5104** could determine which step of the surgical procedure is being performed or will subsequently be performed and whether particular data or comparisons between data will be required for that step of the surgical procedure. The surgical hub **5104** can be configured to automatically call up data screens based upon the step of the surgical procedure being performed, without waiting for the surgeon to ask for the particular information.

[0288] Another benefit includes checking for errors during the setup of the surgical procedure or during the course of the surgical procedure. For example, a situationally aware surgical hub **5104** could determine whether the operating theater is setup properly or optimally for the surgical procedure to be performed. The surgical hub **5104** can be configured to determine the type of surgical procedure being performed, retrieve the corresponding checklists, product location, or setup needs (e.g., from a memory), and then compare the current operating theater layout to the standard layout for the type of surgical procedure that the surgical hub **5104** determines is being performed. In one exemplification, the surgical hub **5104** can be configured to compare the list of

items for the procedure scanned by a suitable scanner for example and/or a list of devices paired with the surgical hub **5104** to a recommended or anticipated manifest of items and/or devices for the given surgical procedure. If there are any discontinuities between the lists, the surgical hub **5104** can be configured to provide an alert indicating that a particular modular device **5102**, patient monitoring device **5124**, and/or other surgical item is missing. In one exemplification, the surgical hub **5104** can be configured to determine the relative distance or position of the modular devices **5102** and patient monitoring devices **5124** via proximity sensors, for example. The surgical hub **5104** can compare the relative positions of the devices to a recommended or anticipated layout for the particular surgical procedure. If there are any discontinuities between the layouts, the surgical hub **5104** can be configured to provide an alert indicating that the current layout for the surgical procedure deviates from the recommended layout.

[0289] As another example, a situationally aware surgical hub **5104** could determine whether the surgeon (or other medical personnel) was making an error or otherwise deviating from the expected course of action during the course of a surgical procedure. For example, the surgical hub **5104** can be configured to determine the type of surgical procedure being performed, retrieve the corresponding list of steps or order of equipment usage (e.g., from a memory), and then compare the steps being performed or the equipment being used during the course of the surgical procedure to the expected steps or equipment for the type of surgical procedure that the surgical hub **5104** determined is being performed. In one exemplification, the surgical hub **5104** can be configured to provide an alert indicating that an unexpected action is being performed or an unexpected device is being utilized at the particular step in the surgical procedure.

[0290] Overall, the situational awareness system for the surgical hub **5104** improves surgical procedure outcomes by adjusting the surgical instruments (and other modular devices **5102**) for the particular context of each surgical procedure (such as adjusting to different tissue types) and validating actions during a surgical procedure. The situational awareness system also improves surgeons' efficiency in performing surgical procedures by automatically suggesting next steps, providing data, and adjusting displays and other modular devices **5102** in the surgical theater according to the specific context of the procedure.

[0291] Referring now to FIG. **15**, a timeline **5200** depicting situational awareness of a hub, such as the surgical hub **106** or **206** (FIGS. **1-11**), for example, is depicted. The timeline **5200** is an illustrative surgical procedure and the contextual information that the surgical hub **106**, **206** can derive from the data received from the data sources at each step in the surgical procedure. The timeline **5200** depicts the typical steps that would be taken by the nurses, surgeons, and other medical personnel during the course of a lung segmentectomy procedure, beginning with setting up the operating theater and ending with transferring the patient to a post-operative recovery room.

[0292] The situationally aware surgical hub **106**, **206** receives data from the data sources throughout the course of the surgical procedure, including data generated each time medical personnel utilize a modular device that is paired with the surgical hub **106**, **206**. The surgical hub **106**, **206** can receive this data from the paired modular devices and other data sources and continually derive inferences (i.e., contextual information) about the ongoing procedure as new data is received, such as which step of the procedure is being performed at any given time. The situational awareness system of the surgical hub **106**, **206** is able to, for example, record data pertaining to the procedure for generating reports, verify the steps being taken by the medical personnel, provide data or prompts (e.g., via a display screen) that may be pertinent for the particular procedural step, adjust modular devices based on the context (e.g., activate monitors, adjust the field of view (FOV) of the medical imaging device, or change the energy level of an ultrasonic surgical instrument or RF electrosurgical instrument), and take any other such action described above.

[0293] As the first step **5202** in this illustrative procedure, the hospital staff members retrieve the patient's EMR from the hospital's EMR database. Based on select patient data in the EMR, the

surgical hub **106**, **206** determines that the procedure to be performed is a thoracic procedure.

[0294] Second step **5204**, the staff members scan the incoming medical supplies for the procedure. The surgical hub **106**, **206** cross-references the scanned supplies with a list of supplies that are utilized in various types of procedures and confirms that the mix of supplies corresponds to a thoracic procedure. Further, the surgical hub **106**, **206** is also able to determine that the procedure is not a wedge procedure (because the incoming supplies either lack certain supplies that are necessary for a thoracic wedge procedure or do not otherwise correspond to a thoracic wedge procedure).

[0295] Third step **5206**, the medical personnel scan the patient band via a scanner that is communicably connected to the surgical hub **106**, **206**. The surgical hub **106**, **206** can then confirm the patient's identity based on the scanned data.

[0296] Fourth step **5208**, the medical staff turns on the auxiliary equipment. The auxiliary equipment being utilized can vary according to the type of surgical procedure and the techniques to be used by the surgeon, but in this illustrative case they include a smoke evacuator, insufflator, and medical imaging device. When activated, the auxiliary equipment that are modular devices can automatically pair with the surgical hub **106**, **206** that is located within a particular vicinity of the modular devices as part of their initialization process. The surgical hub **106**, **206** can then derive contextual information about the surgical procedure by detecting the types of modular devices that pair with it during this pre-operative or initialization phase. In this particular example, the surgical hub **106**, **206** determines that the surgical procedure is a VATS procedure based on this particular combination of paired modular devices. Based on the combination of the data from the patient's EMR, the list of medical supplies to be used in the procedure, and the type of modular devices that connect to the hub, the surgical hub **106**, **206** can generally infer the specific procedure that the surgical team will be performing. Once the surgical hub **106**, **206** knows what specific procedure is being performed, the surgical hub **106**, **206** can then retrieve the steps of that procedure from a memory or from the cloud and then cross-reference the data it subsequently receives from the connected data sources (e.g., modular devices and patient monitoring devices) to infer what step of the surgical procedure the surgical team is performing.

[0297] Fifth step **5210**, the staff members attach the EKG electrodes and other patient monitoring devices to the patient. The EKG electrodes and other patient monitoring devices are able to pair with the surgical hub **106**, **206**. As the surgical hub **106**, **206** begins receiving data from the patient monitoring devices, the surgical hub **106**, **206** thus confirms that the patient is in the operating theater.

[0298] Sixth step **5212**, the medical personnel induce anesthesia in the patient. The surgical hub **106**, **206** can infer that the patient is under anesthesia based on data from the modular devices and/or patient monitoring devices, including EKG data, blood pressure data, ventilator data, or combinations thereof, for example. Upon completion of the sixth step **5212**, the pre-operative portion of the lung segmentectomy procedure is completed and the operative portion begins.

[0299] Seventh step **5214**, the patient's lung that is being operated on is collapsed (while ventilation is switched to the contralateral lung). The surgical hub **106**, **206** can infer from the ventilator data that the patient's lung has been collapsed, for example. The surgical hub **106**, **206** can infer that the operative portion of the procedure has commenced as it can compare the detection of the patient's lung collapsing to the expected steps of the procedure (which can be accessed or retrieved previously) and thereby determine that collapsing the lung is the first operative step in this particular procedure.

[0300] Eighth step **5216**, the medical imaging device (e.g., a scope) is inserted and video from the medical imaging device is initiated. The surgical hub **106**, **206** receives the medical imaging device data (i.e., video or image data) through its connection to the medical imaging device. Upon receipt of the medical imaging device data, the surgical hub **106**, **206** can determine that the laparoscopic portion of the surgical procedure has commenced. Further, the surgical hub **106**, **206** can determine

that the particular procedure being performed is a segmentectomy, as opposed to a lobectomy (note that a wedge procedure has already been discounted by the surgical hub **106**, **206** based on data received at the second step **5204** of the procedure). The data from the medical imaging device **124** (FIG. **2**) can be utilized to determine contextual information regarding the type of procedure being performed in a number of different ways, including by determining the angle at which the medical imaging device is oriented with respect to the visualization of the patient's anatomy, monitoring the number or medical imaging devices being utilized (i.e., that are activated and paired with the surgical hub **106**, **206**), and monitoring the types of visualization devices utilized. For example, one technique for performing a VATS lobectomy places the camera in the lower anterior corner of the patient's chest cavity above the diaphragm, whereas one technique for performing a VATS segmentectomy places the camera in an anterior intercostal position relative to the segmental fissure. Using pattern recognition or machine learning techniques, for example, the situational awareness system can be trained to recognize the positioning of the medical imaging device according to the visualization of the patient's anatomy. As another example, one technique for performing a VATS lobectomy utilizes a single medical imaging device, whereas another technique for performing a VATS segmentectomy utilizes multiple cameras. As yet another example, one technique for performing a VATS segmentectomy utilizes an infrared light source (which can be communicably coupled to the surgical hub as part of the visualization system) to visualize the segmental fissure, which is not utilized in a VATS lobectomy. By tracking any or all of this data from the medical imaging device, the surgical hub **106**, **206** can thereby determine the specific type of surgical procedure being performed and/or the technique being used for a particular type of surgical procedure.

[0301] Ninth step **5218**, the surgical team begins the dissection step of the procedure. The surgical hub **106**, **206** can infer that the surgeon is in the process of dissecting to mobilize the patient's lung because it receives data from the RF or ultrasonic generator indicating that an energy instrument is being fired. The surgical hub **106**, **206** can cross-reference the received data with the retrieved steps of the surgical procedure to determine that an energy instrument being fired at this point in the process (i.e., after the completion of the previously discussed steps of the procedure) corresponds to the dissection step. In certain instances, the energy instrument can be an energy tool mounted to a robotic arm of a robotic surgical system.

[0302] Tenth step **5220**, the surgical team proceeds to the ligation step of the procedure. The surgical hub **106**, **206** can infer that the surgeon is ligating arteries and veins because it receives data from the surgical stapling and cutting instrument indicating that the instrument is being fired. Similarly to the prior step, the surgical hub **106**, **206** can derive this inference by cross-referencing the receipt of data from the surgical stapling and cutting instrument with the retrieved steps in the process. In certain instances, the surgical instrument can be a surgical tool mounted to a robotic arm of a robotic surgical system.

[0303] Eleventh step **5222**, the segmentectomy portion of the procedure is performed. The surgical hub **106**, **206** can infer that the surgeon is transecting the parenchyma based on data from the surgical stapling and cutting instrument, including data from its cartridge. The cartridge data can correspond to the size or type of staple being fired by the instrument, for example. As different types of staples are utilized for different types of tissues, the cartridge data can thus indicate the type of tissue being stapled and/or transected. In this case, the type of staple being fired is utilized for parenchyma (or other similar tissue types), which allows the surgical hub **106**, **206** to infer that the segmentectomy portion of the procedure is being performed.

[0304] Twelfth step **5224**, the node dissection step is then performed. The surgical hub **106**, **206** can infer that the surgical team is dissecting the node and performing a leak test based on data received from the generator indicating that an RF or ultrasonic instrument is being fired. For this particular procedure, an RF or ultrasonic instrument being utilized after parenchyma was transected corresponds to the node dissection step, which allows the surgical hub **106**, **206** to make this

inference. It should be noted that surgeons regularly switch back and forth between surgical stapling/cutting instruments and surgical energy (i.e., RF or ultrasonic) instruments depending upon the particular step in the procedure because different instruments are better adapted for particular tasks. Therefore, the particular sequence in which the stapling/cutting instruments and surgical energy instruments are used can indicate what step of the procedure the surgeon is performing. Moreover, in certain instances, robotic tools can be utilized for one or more steps in a surgical procedure and/or handheld surgical instruments can be utilized for one or more steps in the surgical procedure. The surgeon(s) can alternate between robotic tools and handheld surgical instruments and/or can use the devices concurrently, for example. Upon completion of the twelfth step **5224**, the incisions are closed up and the post-operative portion of the procedure begins.

[0305] Thirteenth step **5226**, the patient's anesthesia is reversed. The surgical hub **106**, **206** can infer that the patient is emerging from the anesthesia based on the ventilator data (i.e., the patient's breathing rate begins increasing), for example.

[0306] Lastly, the fourteenth step **5228** is that the medical personnel remove the various patient monitoring devices from the patient. The surgical hub **106**, **206** can thus infer that the patient is being transferred to a recovery room when the hub loses EKG, BP, and other data from the patient monitoring devices. As can be seen from the description of this illustrative procedure, the surgical hub **106**, **206** can determine or infer when each step of a given surgical procedure is taking place according to data received from the various data sources that are communicably coupled to the surgical hub **106**, **206**.

[0307] Situational awareness is further described in U.S. Provisional Patent Application Ser. No. 62/659,900, titled METHOD OF HUB COMMUNICATION, filed Apr. 19, 2018, which is herein incorporated by reference in its entirety. In certain instances, operation of a robotic surgical system, including the various robotic surgical systems disclosed herein, for example, can be controlled by the hub **106**, **206** based on its situational awareness and/or feedback from the components thereof and/or based on information from the cloud **104**.

Recommendations from Analysis of Procedure Variables

[0308] In various aspects, computer systems, such as the surgical hubs **106**, **206** described in connection with FIGS. **1-11**, can be programmed to compare variables associated with a given surgical procedure to data sets that are collected and aggregated by individual surgical hubs, networks of surgical hubs, cloud computing systems described under the heading CLOUD SYSTEM HARDWARE AND FUNCTIONAL MODULES (which can in turn be connected to surgical hubs), or other computer systems. The data sets can include data pertaining to a variety of variables for different types of surgical procedures, surgical instruments, surgical personnel, and so on. The data set can be evaluated to determine baselines against which procedural variables can be compared. In various aspects, a computer system can be programmed to evaluate for a given surgical procedure the cost-effectiveness of a particular surgical device setup, the procedural outcomes associated with different types of surgical devices, and so on by comparing the analyzed procedural variables with their associated baselines that are determined from the aggregated data. In various aspects, a computer system can be programmed to notify users if the analyzed variables deviated from their associated baselines and provide recommendations accordingly.

[0309] As described above under the heading SURGICAL HUBS, computer systems, such as the surgical hubs **106**, **206** (FIGS. **1-11**), can be connected to or paired with a variety of surgical devices, such as surgical instruments, generators, smoke evacuators, displays, and so on. Through their connections to these surgical devices, the surgical hubs **206** can receive an array of perioperative data from these paired surgical devices while the devices are in use during a surgical procedure. Further, as described above under the heading SITUATIONAL AWARENESS, surgical hubs **206** can determine the context of the surgical procedure being performed (e.g., the procedure type or the step of the procedure being performed) based, at least in part, on perioperative data received from these connected surgical devices. Based on this perioperative data and the surgical

context, the surgical hubs **206** can determine procedural variables associated with the surgical procedure, such as how much time the procedure (or a step thereof) is taking, what surgical instrument is currently being used, and so on. In one aspect, a computer system, such as a surgical hub **206**, can be programmed to provide recommendations by monitoring procedural variables to ascertain when the surgical staff is performing a surgical procedure in a manner that deviates from baselines or expectations for the particular procedure type. For example, FIG. **16** is a logic flow diagram for a process **210000** of providing surgical recommendations, in accordance with at least one aspect of the present disclosure. The process **210000** can be executed by a processor or control circuit of a computer system, such as the processor **244** of the surgical hub **206** illustrated in FIG. **10**. Accordingly, the process **210000** can be embodied as a set of computer-executable instructions stored in a memory **249** that, when executed by the processor **244**, cause the computer system (e.g., a surgical hub **206**) to perform the described steps.

[0310] Accordingly, the processor **244** executing the process **210000** receives **210002** perioperative data from the surgical device(s) connected or paired with the surgical hub **206** and determines **210004** the surgical context based at least in part on the received perioperative data utilizing situational awareness. The surgical context determined by the surgical hub **206** through situational awareness can be utilized to inform evaluations of the surgical staff performing the surgical procedure.

[0311] Accordingly, the processor **244** determines **210006** a procedural variable associated with the surgical procedure based on the surgical context and the perioperative data from the connected surgical devices. The procedural variable can include any aspect or characteristic of the surgical procedure that can vary between individual performances of the surgical procedure type. For example, the procedural variable can include the length of time for the surgical procedure as a whole, the length of time for a particular step of the surgical procedure, the type of surgical instrument being utilized, the costs (e.g., maintenance costs and replacement costs) associated with surgical devices, the type of staple cartridge being utilized in a surgical stapler, the power level or mode of an ultrasonic surgical instrument or an electrosurgical instrument, and the surgical device setup for the procedure (i.e., the preoperative assortment of surgical devices selected for the procedure). The processor **244** can monitor a single procedural variable or multiple procedural variables. In one aspect, the surgical hub **206** can monitor the status of every procedural variable that it has been programmed to determine. In another aspect, the surgical hub **206** can monitor one or more procedural variables that have been selected or programmed by users.

[0312] Accordingly, the processor **244** compares **210008** the determined procedural variable (or variables) to a corresponding baseline (or baselines). Further, the baseline can correspond to or otherwise depend upon the determined surgical context. In one aspect, the surgical hub **206** can retrieve the baseline corresponding to the procedural variable and the surgical context from its memory **249**. In another aspect, the surgical hub **206** can retrieve the baseline from a cloud computing system, as is described under the heading CLOUD SYSTEM HARDWARE AND FUNCTIONAL MODULES, that is communicably connected to the surgical hub **206**. In one aspect, the cloud computing system can aggregate data across all of the surgical hubs **206** connected thereto and calculate corresponding baselines for the procedural variables of various types of surgical procedures. The baselines for different procedural variables can be determined from the data aggregated from individual surgical hubs **206** or networks of surgical hubs **206** by averaging the data (e.g., the average length of time to complete a step of a surgical procedure), determining the most common instance of the procedural variable (e.g., the most common type of surgical instrument utilized for a surgical procedure or a step thereof), determining which instance of the procedural variable is most correlated with positive procedural outcomes (e.g., the force to fire a surgical stapling and cutting instrument that is associated with the least amount of bleeding for a given tissue type), and so on. Further, the baselines can be aggregated according to surgical metadata (e.g., surgical contextual data determined via situational awareness or patient data from

an electronic medical record (EMR)), such as tissue thickness for firings of a surgical instrument and comorbidities suffered by the patient at the time of the surgical procedure, in order to ensure that the determined procedural variables are compared to relevant baselines.

[0313] Based on the results of the comparison between the determined procedural variable and its corresponding baseline, the surgical hub **206** can take various actions in response. In one aspect, the processor **244** provides **210010** a notification or recommendation according to whether the determined procedural variable deviates from its corresponding baseline. The recommendation can vary depending upon the particular type of procedural variable that is being compared. The recommendation can be for the user to utilize a different surgical instrument (e.g., an instrument with smaller jaws, a larger maximum articulation angle, or a longer shaft), utilize a different trocar or other access point, change the patient's position on the surgical table (e.g., roll the patient), and so on.

[0314] In one aspect, the recommendations provided **210010** by the process **210000** illustrated in FIG. **16** can be delivered in real time (i.e., during the course of the surgical procedure). For example, FIG. **17** illustrates a prophetic implementation of the process **210000** where the provided recommendations can be overlaid a displayed live video feed during the course of a surgical procedure, in accordance with at least one aspect of the present disclosure. The video feed can be supplied by, for example, an endoscope **239** (FIG. **9**) communicably coupled to the surgical hub **206** that is being utilized to visualize a surgical site **210102** during the surgical procedure. The video feed from the endoscope **239** can be displayed on a hub display **215** (FIG. **9**), a local display **217** (FIG. **10**), non-sterile displays **107**, **109** (FIG. **2**), a sterile primary display **119** (FIG. **2**), and other such display devices that are viewable by the surgical staff during the surgical procedure.

[0315] In the first image **210100***a*, the surgeon is raising a vessel for transection during a lobectomy procedure. In a lobectomy procedure, the pulmonary vessels that supply blood to the lobe of the lung that is the subject of the procedure must be dissected out and transected. These pulmonary vessels are typically fragile and have a very high volume of blood flowing through them. Therefore, the dissection is delicate and a mistake can be fatal for the patient. Further, the orientation of the pulmonary vessels is not always predictable, which makes trocar placement difficult to optimize. If the orientation of the pulmonary vessels is poor with respect to the location of the trocars, the surgical procedure may be awkward or especially challenging for the surgeon. Therefore, it would be highly beneficial for a computer system, such as the surgical hub **206**, to recognize when the surgeon performing the particular procedure is having difficulty and provide intraoperative recommendations to assist the surgeon.

[0316] In the second image **210100***b*, the surgeon is attempting to transect the vessel with a straight-tipped vascular stapler **210106**. As discussed above in connection with FIG. **16**, the surgical hub **206** can monitor a variety of different procedural variables during the course of the surgical procedure. For example, the surgical hub **206** executing the process **210000** can determine that the surgeon is taking longer than the median or average length of time for this particular procedural step. In other words, the surgical step time procedural variable deviates from the baseline step time for the given procedural step. As another example, the surgical hub **206** executing the process **210000** can determine that the surgeon is utilizing a different surgical instrument type (i.e., a straight-tip vascular stapler **210106**) than the most commonly used surgical instrument type for this particular surgical step (i.e., a curved-tip vascular stapler **210108**). A straight-tip vascular stapler **210106** is a general-purpose stapler, whereas a curved-tip vascular stapler **210108** is specifically designed for this particular type of task. In other words, the instrument type procedural variable deviates from the baseline instrument type for the given procedural step. Accordingly, the surgical hub **206** provides a recommendation for the user to utilize a different vascular stapler, specifically, a vascular stapler that has a curved tip. As yet another example, the surgical hub **206** executing the process **210000** can determine that the vascular stapler **210106** has been introduced to and removed from the patient multiple times

without being fired and/or that additional dissection is being performed by the surgeon while the stapler is removed. Either of these factors can suggest that the surgeon is struggling with the placement of the vascular stapler **210106**. In other words, the procedural variable for the number of times that the surgical instrument is being introduced to/removed from the patient thus deviates from the corresponding baselines for the given procedural step. Alternatively, the procedural variable for the amount of additional dissection being performed thus deviates from the corresponding baselines for the given procedural step.

[0317] In one aspect, the surgical hub **206** is programmed to determine the recommendation based on the surgical context and the given procedural variables and then access the inventory database of the medical facility to determine whether the recommended alternative is available to the medical facility. If the recommended alternative is not available, the surgical hub **206** can be programmed to not make the recommendation intraoperatively or otherwise record that the alternative surgical device would have been recommended had it been available. If the recommended alternative is available, the surgical hub **206** can be programmed to provide the intraoperative recommendation, as discussed above. In one aspect, the recommendation can be provided as an icon **210104** or graphical overlay on the displayed live video feed. In other aspects, the recommendation can be provided on a separate display, via audio through a speaker, and so on. After receiving the recommendation, the surgeon switches to the recommended curved-tip vascular stapler **210108**, as indicated by the third image **210100***c*, and then completes the given step of the surgical procedure, as indicated by the fourth image **210100***d* of the video feed.

[0318] In another prophetic implementation of the process **210000** where recommendations are provided intraoperatively, the surgical hub **206** could be programmed to determine when the surgical staff is preparing to place the trocars for a laparoscopic procedure (e.g., through situational awareness) or if the surgical staff is having difficulties in performing a procedure due to poor trocar placement. Accordingly, the surgical hub **206** can then recommend placement locations for the trocars and/or specific types of trocars to use on a display coupled to the surgical hub **206**. The recommended placement locations and trocar types can be selected to maximize accessibility to target tissue for the given surgical procedure. The recommendations provided by this implementation of the process **210000** can be based on, for example, preoperative imaging of the target tissue (which can indicate whether a target tissue, such as a lymph node, will be difficult to access), an inference as to the location of the target tissue from outside the body by aligning the preoperative imaging data with the patient, intraoperative imaging of the target tissue (e.g., image data captured via an endoscope **239**), imaging of the operating room (OR) via a camera assembly (which can include cameras positioned around the OR or cameras worn by the surgical staff, for example), available surgical device types (e.g., whether particular surgical devices are already opened on the prep table or what surgical devices are available in the medical facility), and whether the surgical hub **206** has determined that the surgical staff has been having difficulty with an ongoing procedure (e.g., the duration of time spent on a procedural step or the number of instrument exchanges for the procedural step is deviating from a baseline). Imaging the OR via a camera assembly can be beneficial to, for example, determine the positioning of the patient on the OR table (e.g., whether the patient is in the Trendelenburg position, supine, or in the lithotomy position), where trocars are already positioned in the patient, potential positions where the surgeons and/or assistants could be located when performing the surgical procedure, and locations of potential obstructions within the OR (which could affect optimal trocar positioning). In addition to suggesting particular trocar positions and trocar types, the surgical hub **206** can also be programmed to provide other types of recommendations based on these procedural variables, such as an alternative surgical device (e.g., a different grasper with smaller jaws, a surgical instrument having a larger maximum articulation angle, or a surgical instrument having a longer shaft), shifting the position of a surgical instrument with respect to the currently placed trocars (e.g., moving a surgical instrument from one trocar to another trocar), shifting the position of the patient

on the surgical table (e.g., increase the angle of the table or roll the patient), and so on.

[0319] In another aspect, the recommendations provided **210010** by the process **210000** illustrated in FIG. **16** can be delivered outside of the surgical procedure, such as during a postoperative playback of the surgical procedure. For example, FIG. **18** illustrates a prophetic implementation of the process **210000** where the recommendations can be provided via a graphical user interface **210200** for replaying a surgical procedure, in accordance with at least one aspect of the present disclosure. The graphical user interface **210200** can be displayed on a hub display **215**, for example. The graphical user interface **210200** can include the video feed from the surgical procedure (e.g., the video feed captured by the endoscope **239**) with various graphical controls, icons, and/or prompts thereon or otherwise associated therewith for relaying information to the user or allowing the user to control the video playback. For example, the graphical user interface **210200** can display an icon **210208** relaying surgical contextual information or perioperative data received from the connected surgical devices corresponding to the current time stamp of the displayed video feed. As another example, the graphical user interface **210200** can display another icon **210210** relaying the recommendation (e.g., from the process **210000**) corresponding to the current time stamp of the displayed video feed. As yet another example, the graphical user interface **210200** can display a progress bar **210202** for indicating the particular portion of the video currently being viewed and controlling the displayed video. The progress bar **210202** can include, for example, a slider widget **210206** for controlling the video playback and icons **210204** visually indicating at what points the surgical hub **206** or other computed system determined a monitored procedural variable deviated from its corresponding baseline. By visually indicating when the computer system determined that the surgeon was deviating from baselines during the surgical procedure via the icons **210204**, the surgeon can focus on those portions of the surgical procedure during the postoperative review of the procedure.

[0320] In one aspect, the graphical user interface **210200** can be configured to overlay a recommended alternative surgical device over the surgical device shown in the video feed to demonstrate to the surgeon how the step of the procedure could have proceeded differently with the alternative surgical device. Further, the graphical user interface **210200** can combine data from recorded video feeds of multiple surgical procedures to show the surgeon his or her movement or technique patterns, where the surgeon differs from peers, where the surgeon can change his or her patterns to optimize outcomes relative to peers, and/or when and where particular surgical device types, techniques, or positions are strongly correlated with outcomes for the given procedure type or step thereof.

[0321] In another aspect, the recommendations provided **210010** by the process **210000** illustrated in FIG. **16** can be delivered as reports with historical data, statistics, or other evidence supporting the provided recommendations. For example, FIG. **19** illustrates a prophetic implementation of the process **210000** where the recommendations associated with surgical procedures can be provided via a graphical user interface **210300** for displaying the historical data underlying the recommendation, in accordance with at least one aspect of the present disclosure. By understanding the basis behind a particular recommendation, users may be more likely to adopt the perioperative recommendations provided by the surgical hub **206**.

[0322] The historical data underlying the recommendations provided by the surgical hub **206** can be provided in a number of different graphical formats, including as graphs, charts, raw data, and so on. In the illustrated implementation, the graphical user interface **210300** is displaying a recommendation for which particular type of surgical instrument should be utilized during a particular surgical procedure and the historical data on which the recommendation is based. The graphical user interface **210300** can display a graph **210302** including a vertical axis **210304** indicating the number of instances various types of surgical instruments have been utilized for the surgical procedure and a horizontal axis **210306** indicating the surgical instrument types. Further, the uses for each surgical instrument type can be subdivided by the number of positive and negative

procedural outcomes. This allows users to visualize whether each surgical instrument type is correlated with positive or negative outcomes, in addition to visualizing the total number of times that the instrument was utilized in a surgical procedure. Accordingly, the recommendation, which can be indicated by an icon **210308** within the graphical user interface **210300**, can correspond to the surgical instrument that has been utilized the most times during surgical procedures, is most correlated with positive procedural outcomes, is least correlated with negative procedural outcomes, and so on.

[0323] In one aspect, the historical data illustrated in the graphical user interface **210300** in FIG. **19** can be provided in addition to intraoperative or postoperative recommendations, as discussed above in FIGS. **17** and **18**, respectively. For example, a user can retrieve the historical data on which a given recommendation is based via, for example, a menu in a graphical user interface displayed by the surgical hub **206**. In one aspect, the surgical hub **206** can be programmed to provide both intraoperative and postoperative recommendations and/or reports to users. In one aspect, the surgical hub **206** can be programmed to provide product information, historical data, and other data associated with alternative surgical instruments recommended for a given surgical procedure.

[0324] In some cases, the recommendations that the surgical hub **206** is programmed to provide can be predetermined or set by administrators of the computer network to which the surgical hub **206** is connected, rather than being determined by the computer system itself from the aggregated data. For example, Daniel L. Miller et al., *Impact of Powered and Tissue-Specific Endoscopic Stapling Technology on Clinical and Economic Outcomes of Video-Assisted Thoracic Surgery Lobectomy Procedures: A Retrospective, Observational Study*, Advances in Therapy, May 2018, 35(5), p. 707-23, demonstrates that a tissue-specific stapler is associated with better patient outcomes and lower hospital costs. Accordingly, a network administrator could program or set a rule that causes any surgical hubs **206** to provide recommendations in accordance with this research. Such predetermined recommendations can be based on external research, such as white papers. In one aspect, the surgical hub **206** can be programmed to provide access to the external research on which the particular recommendations are based via, for example, a link or widget supplied by the graphical user interface providing the intraoperative or postoperative recommendations.

[0325] In one aspect, a computer system can be configured to collect, analyze, and compare published external research and other data sets against outcomes in the medical facility or the network of surgical hubs **206**. The computer system can, in some aspects, mimic the analytical procedure performed by the particular piece of research to confirm the research. If the research is confirmed, then the computer system can provide recommendations corresponding to the research. For example, the Miller et al. paper referenced above shows that powered staplers are associated with fewer hemostasis-related complications and lower procedure costs, particular instrument types (e.g., powered staplers) are associated with fewer hemostasis-related complications than other instrument types (e.g., manual staplers), and the effect size is larger in patients with chronic obstructive pulmonary disease (COPD). Accordingly, when this research is confirmed, the computer system can automatically implement corresponding recommendations dictated by the research throughout the network of surgical hubs **206**.

[0326] In one aspect, the surgical hub **206** can be programmed to highlight the specific feature of an alternative product that makes the alternative product superior. Returning to the example discussed in connection with FIG. **17**, the surgical hub **206** could be programmed to indicate that the curved-tip vascular stapler **210108** is recommended over the straight-tip vascular stapler **210106** because its curved tip is easier to maneuver around vascular structures and is easier see than the straight tip. In another aspect, the surgical hub **206** can be programmed to directly compare a variety of statistics between two products as part of the provided recommendation. Returning again to FIG. **17**, the surgical hub **206** could be programmed to display the difference in average surgical procedure time, differences in procedural outcomes, and other such statistics for surgeons that utilized the curved-tip vascular stapler **210108** compared to surgeons that utilized the straight-

tip vascular stapler **210106**.

[0327] As discussed above with respect to FIGS. **17-18**, a computer system executing the process **210000** illustrated in FIG. **16** can provide intraoperative and/or postoperative recommendations for alternative products, such as surgical instruments. However, a computer system executing the process **210000** can provide recommendations for alternative products in a variety of other contexts. In one aspect, the surgical hub **206** can be programmed to determine what type of product is being utilized, calculate costs associated with the given product, and then recommend an alternative product that performs the same or similar as the given product but has lower associated costs. In another aspect, the surgical hub **206** can be programmed to compare combinations of products to recommend particular product setups that are correlated with improved surgical outcomes, are more cost effective, and so on. For example, a surgical hub **206** can be programmed to identify a first product that is being utilized during the surgical procedure and suggest an additional or second product that complements the function of the first product to provide, for example, better results than using the first product alone. As another example, the surgical hub **206** can be programmed to identify the product setup that is going to be utilized for the surgical procedure (e.g., by retrieving a product list from a product or EMR database or visually identifying the surgical products positioned on the prep table via cameras positioned in the OR that are communicably coupled to the surgical hub **206**), determine whether the identified product setup differs from the baseline product setup for the given surgical procedure (e.g., as determined from the aggregated historical data regarding the surgical procedure type), and then recommend an alternative product setup. As part of this recommendation, the surgical hub **206** could present a statistical report of the improvements that could be expected when utilizing the recommended product setup as compared to the current product setup. The expected improvements could, for example, identify where the evaluated product setup differs from best practices (which can be determined by the computer system from the aggregated data or set by administrators of the computer system) for the given surgical procedure, present the costs associated with the evaluated product setup compared to the recommended product setup, or identify improved surgical outcomes associated with the recommended product setup as compared to the evaluated product setup. Accordingly, the surgical staff can review the recommendations and decide whether they wish to follow them in light of the expected improvements.

[0328] In various aspects, a computer system executing the process **210000** illustrated in FIG. **16** can be further programmed to indicate the impact of knockoffs and reprocessing on surgical outcomes and provide that data to users. In one aspect, a procedural variable evaluated by the process **210000** can include whether a surgical device being utilized in the surgical procedure is authorized or unauthorized (i.e., is a knockoff or was reprocessed) and the corresponding baseline can be the surgical device being an authorized surgical device. In other words, the process **210000** can evaluate whether a surgical device is authorized and, if the surgical device is unauthorized, provide an intraoperative or postoperative recommendation for the surgical staff to instead utilize an authorized surgical device. As part of the provided recommendation, the surgical hub **206** can provide a variety of qualitative and quantitative evidence supporting the recommendation to not utilize the knockoff or reprocessed surgical device.

[0329] In one aspect, the computer system executing the process **210000** can be configured to determine or quantify the effects of unauthentic surgical devices. The computer system can detect whether a surgical device has been reprocessed in an authorized manner in a variety of different ways, including whether a usage counter (e.g., stored in the memory of the surgical device) exceeds a limit, which indicates that the surgical device is being used beyond its intended lifespan. The computer system can detect whether a surgical device is a knockoff in a variety of different ways, including whether the surgical device is able to transmit a security key properly identifying the surgical device to the computer system. Accordingly, when the surgical hub **206** detects an unauthorized surgical device in use during a surgical procedure, the surgical hub **206** can record

functions of the unauthorized surgical device and the corresponding outcomes. Accordingly, the functions and outcomes of using unauthorized surgical devices can be compared with those resulting from authorized surgical devices and presented to users as reports or as evidence supporting a recommendation to utilize an authorized surgical device. For example, variances between the performance of unauthorized surgical devices and authorized surgical devices could be highlighted in a regularly generated (e.g., compiled weekly) report on the medical facility. As another example, the computer system could track the number of times that a surgical device has been resterilized and identify the number of times where resterilization begins to affect the performance of the surgical device. As another example, the computer system could show what steps or operations of the procedure were adversely affected by the unauthorized surgical device. As yet another example, the computer system could identify the number of damaged or replaced products in the OR resulting from the unauthorized products. In one aspect, if a surgical device is reprocessed through authorized reprocessing channels, the functions and outcomes of the surgical device could be monitored and highlighted in a regularly generated (e.g., compiled weekly) report on the medical facility.

[0330] In one aspect, the functions and outcomes associated with an individual surgical device can be compared against itself, rather than a baseline defined for the surgical device type, to determine whether there is any degradation in the performance of the surgical device over time. Such analyses can be useful in order to determine when a surgical device should be replaced or undergo maintenance, for example. Reports on functions and outcomes associated with individual surgical devices could be highlighted in a regularly generated (e.g., compiled weekly) report on the medical facility, for example.

[0331] In one aspect, the computer system can be configured to compare different brands of products and provide recommendations accordingly. For example, the computer system could show when another brand's product delivers the same or better performance at a lower cost than the brand of a given product utilized during a surgical procedure or that is to be used during a surgical procedure.

Examples

[0332] Various aspects of the subject matter described herein are set out in the following numbered examples:

[0333] Example 1. A computer system configured to be communicably coupled to a surgical device. The computer system comprises a processor and a memory coupled to the processor. The memory stores instructions that, when executed by the processor, cause the computer system to: receive perioperative data from the surgical device; determine a surgical context based at least in part on the perioperative data; determine a procedural variable associated with the surgical context; compare the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and provide a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

[0334] Example 2. The computer system of Example 1, wherein the procedural variable comprises a surgical instrument type being utilized during a surgical procedure.

[0335] Example 3. The computer system of Example 2, wherein the notification comprises a recommendation for an alternative surgical instrument type for the surgical procedure.

[0336] Example 4. The computer system of Example 3, wherein the alternative surgical instrument type is associated with improved procedural outcomes for the surgical procedure.

[0337] Example 5. The computer system of Example 1, wherein the procedural variable comprises a surgical procedure length.

[0338] Example 6. The computer system of Example 5, wherein the notification comprises a recommendation for an alternative surgical device setup.

[0339] Example 7. The computer system of Example 1, wherein the procedural variable comprises a cost of surgical devices utilized during a surgical procedure.

[0340] Example 8. The computer system of Example 7, wherein the notification comprises a recommendation for a less-expensive surgical device setup.

[0341] Example 9. A computer-implemented method for providing recommendations associated with a surgical procedure, the method comprising: receiving, by a computer system, perioperative data from a surgical device; determining, by the computer system, a surgical context based at least in part on the perioperative data; determining, by the computer system, a procedural variable associated with the surgical context; comparing, by the computer system, the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and providing, by the computer system, a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

[0342] Example 10. The method of Example 9, wherein the procedural variable comprises a surgical instrument type being utilized during a surgical procedure.

[0343] Example 11. The method of Example 10, wherein the notification comprises a recommendation for an alternative surgical instrument type for the surgical procedure.

[0344] Example 12. The method of Example 11, wherein the alternative surgical instrument type is associated with improved procedural outcomes for the surgical procedure.

[0345] Example 13. The method of Example 9, wherein the procedural variable comprises a surgical procedure length.

[0346] Example 14. The method of Example 13, wherein the notification comprises a recommendation for an alternative surgical device setup.

[0347] Example 15. The method of Example 9, wherein the procedural variable comprises a cost of surgical devices utilized during a surgical procedure.

[0348] Example 16. The method of Example 15, wherein the notification comprises a recommendation for a less-expensive surgical device setup.

[0349] Example 17. A computer system configured to be communicably coupled to a surgical device and a video camera. The computer system comprises a processor and a memory coupled to the processor. The memory stores instructions that, when executed by the processor, cause the computer system to: record a surgical procedure via the video camera; receive perioperative data from the surgical device; determine a surgical context based at least in part on the perioperative data; determine a procedural variable associated with the surgical context; compare the procedural variable to a baseline for the procedural variable, the baseline corresponding to the surgical context; and replay a recording of the surgical procedure, the recording including a notification according to whether the procedural variable deviates from the baseline for the procedural variable.

[0350] Example 18. The computer system of Example 17, wherein the procedural variable comprises a surgical instrument type being utilized during a surgical procedure.

[0351] Example 19. The computer system of Example 18, wherein the notification comprises a recommendation for an alternative surgical instrument type for the surgical procedure.

[0352] Example 20. The computer system of Example 19, wherein the alternative surgical instrument type is associated with improved procedural outcomes for the surgical procedure.

[0353] Example 21. The computer system of Example 17, wherein the procedural variable comprises a surgical procedure length.

[0354] Example 22. The computer system of Example 21, wherein the notification comprises a recommendation for an alternative surgical device setup.

[0355] Example 23. The computer system of Example 17, wherein the procedural variable comprises a cost of surgical devices utilized during a surgical procedure.

[0356] Example 24. The computer system of Example 23, wherein the notification comprises a recommendation for a less-expensive surgical device setup.

[0357] While several forms have been illustrated and described, it is not the intention of Applicant to restrict or limit the scope of the appended claims to such detail. Numerous modifications, variations, changes, substitutions, combinations, and equivalents to those forms may be

implemented and will occur to those skilled in the art without departing from the scope of the present disclosure. Moreover, the structure of each element associated with the described forms can be alternatively described as a means for providing the function performed by the element. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications, combinations, and variations as falling within the scope of the disclosed forms. The appended claims are intended to cover all such modifications, variations, changes, substitutions, modifications, and equivalents.

[0358] The foregoing detailed description has set forth various forms of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, and/or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. Those skilled in the art will recognize that some aspects of the forms disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as one or more program products in a variety of forms, and that an illustrative form of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution.

[0359] Instructions used to program logic to perform various disclosed aspects can be stored within a memory in the system, such as dynamic random access memory (DRAM), cache, flash memory, or other storage. Furthermore, the instructions can be distributed via a network or by way of other computer readable media. Thus a machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer), but is not limited to, floppy diskettes, optical disks, compact disc, read-only memory (CD-ROMs), and magneto-optical disks, read-only memory (ROMs), random access memory (RAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic or optical cards, flash memory, or a tangible, machine-readable storage used in the transmission of information over the Internet via electrical, optical, acoustical or other forms of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.). Accordingly, the non-transitory computer-readable medium includes any type of tangible machine-readable medium suitable for storing or transmitting electronic instructions or information in a form readable by a machine (e.g., a computer).

[0360] As used in any aspect herein, the term "control circuit" may refer to, for example, hardwired circuitry, programmable circuitry (e.g., a computer processor including one or more individual instruction processing cores, processing unit, processor, microcontroller, microcontroller unit, controller, digital signal processor (DSP), programmable logic device (PLD), programmable logic array (PLA), or field programmable gate array (FPGA)), state machine circuitry, firmware that stores instructions executed by programmable circuitry, and any combination thereof. The control circuit may, collectively or individually, be embodied as circuitry that forms part of a larger system, for example, an integrated circuit (IC), an application-specific integrated circuit (ASIC), a system on-chip (SoC), desktop computers, laptop computers, tablet computers, servers, smart phones, etc. Accordingly, as used herein "control circuit" includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated

circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

[0361] As used in any aspect herein, the term "logic" may refer to an app, software, firmware and/or circuitry configured to perform any of the aforementioned operations. Software may be embodied as a software package, code, instructions, instruction sets and/or data recorded on non-transitory computer readable storage medium. Firmware may be embodied as code, instructions or instruction sets and/or data that are hard-coded (e.g., nonvolatile) in memory devices.

[0362] As used in any aspect herein, the terms "component," "system," "module" and the like can refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution.

[0363] As used in any aspect herein, an "algorithm" refers to a self-consistent sequence of steps leading to a desired result, where a "step" refers to a manipulation of physical quantities and/or logic states which may, though need not necessarily, take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It is common usage to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. These and similar terms may be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities and/or states.

[0364] A network may include a packet switched network. The communication devices may be capable of communicating with each other using a selected packet switched network communications protocol. One example communications protocol may include an Ethernet communications protocol which may be capable permitting communication using a Transmission Control Protocol/Internet Protocol (TCP/IP). The Ethernet protocol may comply or be compatible with the Ethernet standard published by the Institute of Electrical and Electronics Engineers (IEEE) titled "IEEE 802.3 Standard", published in December 2008 and/or later versions of this standard. Alternatively or additionally, the communication devices may be capable of communicating with each other using an X.25 communications protocol. The X.25 communications protocol may comply or be compatible with a standard promulgated by the International Telecommunication Union-Telecommunication Standardization Sector (ITU-T). Alternatively or additionally, the communication devices may be capable of communicating with each other using a frame relay communications protocol. The frame relay communications protocol may comply or be compatible with a standard promulgated by Consultative Committee for International Telegraph and Telephone (CCITT) and/or the American National Standards Institute (ANSI). Alternatively or additionally, the transceivers may be capable of communicating with each other using an Asynchronous Transfer Mode (ATM) communications protocol. The ATM communications protocol may comply or be compatible with an ATM standard published by the ATM Forum titled "ATM-MPLS Network Interworking 2.0" published August 2001, and/or later versions of this standard. Of course, different and/or after-developed connection-oriented network communication protocols are equally contemplated herein.

[0365] Unless specifically stated otherwise as apparent from the foregoing disclosure, it is appreciated that, throughout the foregoing disclosure, discussions using terms such as "processing," "computing," "calculating," "determining," "displaying," or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer

system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0366] One or more components may be referred to herein as "configured to," "configurable to," "operable/operative to," "adapted/adaptable," "able to," "conformable/conformed to," etc. Those skilled in the art will recognize that "configured to" can generally encompass active-state components and/or inactive-state components and/or standby-state components, unless context requires otherwise.

[0367] The terms "proximal" and "distal" are used herein with reference to a clinician manipulating the handle portion of the surgical instrument. The term "proximal" refers to the portion closest to the clinician and the term "distal" refers to the portion located away from the clinician. It will be further appreciated that, for convenience and clarity, spatial terms such as "vertical", "horizontal", "up", and "down" may be used herein with respect to the drawings. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and/or absolute.

[0368] Those skilled in the art will recognize that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations.

[0369] In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase "A or B" will be typically understood to include the possibilities of "A" or "B" or "A and B."

[0370] With respect to the appended claims, those skilled in the art will appreciate that recited operations therein may generally be performed in any order. Also, although various operational

flow diagrams are presented in a sequence(s), it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently. Examples of such alternate orderings may include overlapping, interleaved, interrupted, reordered, incremental, preparatory, supplemental, simultaneous, reverse, or other variant orderings, unless context dictates otherwise. Furthermore, terms like "responsive to," "related to," or other past-tense adjectives are generally not intended to exclude such variants, unless context dictates otherwise.

[0371] It is worthy to note that any reference to "one aspect," "an aspect," "an exemplification," "one exemplification," and the like means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases "in one aspect," "in an aspect," "in an exemplification," and "in one exemplification" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner in one or more aspects.

[0372] Any patent application, patent, non-patent publication, or other disclosure material referred to in this specification and/or listed in any Application Data Sheet is incorporated by reference herein, to the extent that the incorporated materials is not inconsistent herewith. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

[0373] In summary, numerous benefits have been described which result from employing the concepts described herein. The foregoing description of the one or more forms has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. The one or more forms were chosen and described in order to illustrate principles and practical application to thereby enable one of ordinary skill in the art to utilize the various forms and with various modifications as are suited to the particular use contemplated. It is intended that the claims submitted herewith define the overall scope.

Claims

1-20. (canceled)

21. A surgical hub comprising a control circuit configured to: receive an authentication request signal from a surgical instrument communicably coupled to the surgical hub, wherein the authentication request signal comprises an authentication credential associated with the surgical instrument; forward the authentication request signal to a cloud server; receive a control program update signal from the cloud server based on forwarding the authentication request signal to the cloud server, wherein the control program update signal comprises an updated control program for the surgical instrument, and wherein the updated control program is executable by the surgical instrument to perform a surgical function; and forward the control program update signal to the surgical instrument causing the surgical instrument to execute the updated control program to perform the surgical function.

22. The surgical hub of claim 21, wherein the surgical function comprises any one or more of tissue clamping, tissue cutting, and tissue sealing, and wherein the control program update comprises a modification to an operational parameter implemented by the surgical instrument for performing the surgical function.

23. The surgical hub of claim 21, wherein the control circuit is configured to: receive a data transmission readiness signal from the surgical instrument, wherein the data transmission readiness

signal indicates that the surgical instrument has transitioned to a configuration for receiving the control program update signal.

24. The surgical hub of claim 23, wherein the control circuit is configured to: transmit perioperative data corresponding to performance of the surgical function by the surgical instrument to the cloud server for storage in an aggregated medical database.

25. The surgical hub of claim 21, wherein the control circuit is configured to: receive a second authentication request signal from a second surgical instrument, wherein the second authentication request signal comprises a second authentication credential associated with the second surgical instrument; forward the second authentication request signal to the cloud server; and receive a lockout instruction signal associated with the second instrument from the cloud server based on forwarding the second authentication request signal.

26. The surgical hub of claim 25, wherein the control circuit is configured to: block signal communications between the second surgical instrument and the cloud server based on receiving the lockout instruction.

27. The surgical hub of claim 25, wherein the control circuit is configured to: receive an authentication credential update signal from the cloud server, wherein the authentication credential update signal comprises a new authentication credential associated with locking out the second surgical instrument.

28. A cloud server comprising a control circuit configured to: receive an authentication request signal from a surgical hub, wherein the authentication request signal comprises an authentication credential associated with a surgical instrument communicably coupled with the surgical hub; transmit authentication approval signal to the surgical hub based on the authentication credential; generate an updated control program for the surgical instrument based on the authentication credential, wherein the updated control program is executable by the surgical instrument to perform a surgical function; and transmit a control program update signal from to the surgical hub, wherein the control program update signal comprises the updated control program for the surgical instrument.

29. The cloud server of claim 28, wherein the surgical function comprises any one or more of tissue clamping, tissue cutting, and tissue sealing, and wherein the control program update comprises a modification to an operational parameter implemented by the surgical instrument for performing the surgical function.

30. The cloud server of claim 28, wherein the control circuit is configured to: receive, via the surgical hub, a data transmission readiness signal from the surgical instrument, wherein the data transmission readiness signal indicates that the surgical instrument has transitioned to a configuration for receiving the control program update signal.

31. The cloud server of claim 30, wherein the control circuit is configured to: receive, via the surgical hub, perioperative data corresponding to performance of the surgical function by the surgical instrument; and store the perioperative data in an aggregated medical database.

32. The cloud server of claim 30, wherein the control circuit is configured to: receive a second authentication request signal from a second surgical hub, wherein the second authentication request signal comprises a second authentication credential associated with a second surgical instrument communicably coupled to the second surgical hub; transmit a lockout instruction signal associated with the second instrument to the second surgical hub based on the second authentication credential.

33. The cloud server of claim 32, wherein the control circuit is configured to: block signal communications from the second surgical instrument.

34. The cloud server of claim 32, wherein the control circuit is configured to: generate a new authentication credential for the second surgical instrument based on determining the second surgical instrument is associated with a manufacturing defect.

35. The cloud server of claim 33, wherein the control circuit is configured to: transmit an

authentication credential update signal to the surgical hub, wherein the authentication credential update signal comprises the new authentication credential for the second surgical instrument.

36. The cloud server of claim 28, wherein the surgical hub is a first surgical hub of a plurality of surgical hubs, wherein the surgical instrument is a first surgical instrument of a plurality of surgical instruments, and wherein the control circuit is configured to: receive, via the plurality of surgical hubs, aggregated perioperative data corresponding to performance of the surgical function by the plurality surgical instruments during a plurality of surgical procedures; and generate the updated control program for the first surgical instrument based on the aggregated perioperative data.

37. A surgical instrument comprising a control circuit configured to: transmit, via a surgical hub, an authentication request signal to a cloud server, wherein the authentication request signal comprises an authentication credential associated with the surgical instrument; transition to a configuration for receiving data from the cloud server based on transmitting the authentication request; transmit, via the surgical hub, a data transmission readiness signal from to the cloud server, wherein the data transmission readiness signal indicates that the surgical instrument has transitioned to the configuration for receiving data from the cloud server; receive, via the surgical hub, a control program update signal from the cloud server, wherein the control program update signal comprises an updated control program for the surgical instrument, and wherein the updated control program is executable by the surgical instrument to perform a surgical function; and execute the updated control program to perform the surgical function during a surgical procedure.

38. The surgical instrument of claim 37, wherein the surgical instrument comprises an end effector configured to interact with patient tissue, wherein the surgical function comprises any one or more of tissue clamping, tissue cutting, and tissue sealing, and wherein the control program update comprises a modification to an operational parameter implemented by the surgical instrument for performing the surgical function.

39. The surgical instrument of claim 37, wherein the control circuit is configured to: generate perioperative data corresponding to the performance of the surgical function; and transmit, via the surgical hub, the perioperative data to the cloud server for storage in an aggregated medical database.

40. The surgical instrument of claim 37, further comprising a wireless transceiver for transmitting signals to and receiving signals from the surgical hub.