July 21, 2023

Brainlab AG
Esther Moreno Garcia
QM Consultant Regulatory Affairs
Olof-Palme-Str. 9
Munich, 81829
Germany

Re: K223288
Trade/Device Name: Cranial Navigation, Navigation Software Cranial, Navigation Software Craniofacial, Cranial EM System, Automatic Registration iMRI
Regulation Number: 21 CFR 882.4560
Regulation Name: Stereotaxic Instrument
Regulatory Class: Class II
Product Code: HAW
Dated: June 20, 2023
Received: June 20, 2023

Dear Esther Moreno Garcia:

We have reviewed your Section 510(k) premarket notification of intent to market the device referenced above and have determined the device is substantially equivalent (for the indications for use stated in the enclosure) to legally marketed predicate devices marketed in interstate commerce prior to May 28, 1976, the enactment date of the Medical Device Amendments, or to devices that have been reclassified in accordance with the provisions of the Federal Food, Drug, and Cosmetic Act (Act) that do not require approval of a premarket approval application (PMA). You may, therefore, market the device, subject to the general controls provisions of the Act. Although this letter refers to your product as a device, please be aware that some cleared products may instead be combination products. The 510(k) Premarket Notification Database located at https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm identifies combination product submissions. The general controls provisions of the Act include requirements for annual registration, listing of devices, good manufacturing practice, labeling, and prohibitions against misbranding and adulteration. Please note: CDRH does not evaluate information related to contract liability warranties. We remind you, however, that device labeling must be truthful and not misleading.

If your device is classified (see above) into either class II (Special Controls) or class III (PMA), it may be subject to additional controls. Existing major regulations affecting your device can be found in the Code of Federal Regulations, Title 21, Parts 800 to 898. In addition, FDA may publish further announcements concerning your device in the Federal Register.

Please be advised that FDA's issuance of a substantial equivalence determination does not mean that FDA has made a determination that your device complies with other requirements of the Act or any Federal

statutes and regulations administered by other Federal agencies. You must comply with all the Act's requirements, including, but not limited to: registration and listing (21 CFR Part 807); labeling (21 CFR Part 801); medical device reporting (reporting of medical device-related adverse events) (21 CFR 803) for devices or postmarketing safety reporting (21 CFR 4, Subpart B) for combination products (see https://www.fda.gov/combination-products/guidance-regulatory-information/postmarketing-safety-reporting-combination-products); good manufacturing practice requirements as set forth in the quality systems (QS) regulation (21 CFR Part 820) for devices or current good manufacturing practices (21 CFR 4, Subpart A) for combination products; and, if applicable, the electronic product radiation control provisions (Sections 531-542 of the Act); 21 CFR 1000-1050.

Also, please note the regulation entitled, "Misbranding by reference to premarket notification" (21 CFR Part 807.97). For questions regarding the reporting of adverse events under the MDR regulation (21 CFR Part 803), please go to https://www.fda.gov/medical-devices/medical-device-safety/medical-device-reporting-mdr-how-report-medical-device-problems.

For comprehensive regulatory information about medical devices and radiation-emitting products, including information about labeling regulations, please see Device Advice (https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance) and CDRH Learn (https://www.fda.gov/training-and-continuing-education/cdrh-learn). Additionally, you may contact the Division of Industry and Consumer Education (DICE) to ask a question about a specific regulatory topic. See the DICE website (https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance/contact-us-division-industry-and-consumer-education-dice) for more information or contact DICE by email (DICE@fda.hhs.gov) or phone (1-800-638-2041 or 301-796-7100).

Sincerely,

Adam D. Pierce -S

Digitally signed by Adam D. Pierce -S
Date: 2023.07.21 11:03:25 -04'00'

Adam D. Pierce, Ph.D.
Assistant Director
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Enclosure

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Food and Drug Administration

Indications for Use

Form Approved: OMB No. 0910-0120
Expiration Date: 06/30/2023
See PRA Statement below.

510(k) Number *(if known)*
K223288

Device Name
Cranial Navigation, Navigation Software Cranial, Navigation Software Craniofacial, Cranial EM System, Automatic Registration iMRI

Indications for Use *(Describe)*
Cranial Navigation

The Cranial Navigation is intended as image-guided planning and navigation system to enable navigated cranial surgery. It links instruments to a virtual computer image space on patient image data being processed by the navigation platform. The system is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, including:

- Cranial Resection
  - Resection of tumors and other lesions
  - Resection of skull-base tumor or other lesions
  - AVM Resection

- Craniofacial Procedures (including cranial and midfacial bones)
  - Tumor Resection
  - Bone Tumor Defect Reconstruction
  - Bone Trauma Defect Reconstruction
  - Bone Congenital Defect Reconstructions
  - Orbital cavity reconstruction procedures
- Removal of foreign objects

Cranial EM System

Cranial EM is intended as an image-guided planning and navigation system to enable neurosurgery procedures. The device is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, such as:
- Cranial Resection
  - o Resection of tumors and other lesions
  - o Resection of skull-base tumor or other lesions
- Intracranial catheter placement

Type of Use *(Select one or both, as applicable)*

☒ Prescription Use (Part 21 CFR 801 Subpart D) ☐ Over-The-Counter Use (21 CFR 801 Subpart C)

CONTINUE ON A SEPARATE PAGE IF NEEDED.

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510(k) Summary

July 21, 2023

General Information	
Manufacturer	Brainlab AG; Olof-Palme-Str.9, 81829, Munich, Germany
Establishment Registration	8043933
Trade Name	• Cranial Navigation • Navigation Software Cranial • Navigation Software Craniofacial • Cranial EM System • Automatic Registration iMRI
Classification Name	Neurological Stereotaxic Instrument
Product Code	HAW
Regulation Number	882.4560
Regulatory Class	Class II
Panel	Neurology
Predicate Device(s)	Primary Predicate: K192703 Cranial Image Guided Surgery System Secondary Predicates: K162929 Stryker Navigation System K213989 Cranial EM System

Contact Information	
Primary Contact	**Alternate Contact**
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1. Indication for Use

Cranial Navigation

The Cranial Navigation is intended as image-guided planning and navigation system to enable navigated cranial surgery. It links instruments to a virtual computer image space on patient image data being processed by the navigation platform.
The system is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, including:

- Cranial Resection
  - Resection of tumors and other lesions
  - Resection of skull-base tumor or other lesions

- AVM Resection

- Craniofacial Procedures (including cranial and midfacial bones)
  - Tumor Resection
  - Bone Tumor Defect Reconstruction
  - Bone Trauma Defect Reconstruction
  - Bone Congenital Defect Reconstructions
  - Orbital cavity reconstruction procedures
  - Removal of foreign objects

Cranial EM System

Cranial EM is intended as an image-guided planning and navigation system to enable neurosurgery procedures.
The device is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, such as:

- Cranial Resection
  - o Resection of tumors and other lesions
  - o Resection of skull-base tumor or other lesions
- Intracranial catheter placement

2. Device Description

The subject device consists of several devices: **Cranial Navigation** using optical tracking technology, its accessory **Automatic Registration iMRI**, and **Cranial EM System** using electromagnetic tracking technology.

Cranial Navigation is an image guided surgery system for navigated treatments in the field of cranial surgery, including the newly added Craniofacial indication. It offers different patient image registration methods and instrument calibration to allow surgical navigation by using optical tracking technology. The device provides different workflows guiding the user through preoperative and intraoperative steps.

The software is installed on a mobile or fixed Image Guided Surgery (IGS) platform to support the surgeon in clinical procedures by displaying tracked instruments in patient's image data. The IGS platforms consist of a mobile Monitor Cart or a fixed ceiling mounted display and an infrared camera for image guided surgery purposes. There are three different product lines of the IGS platforms: "Curve", "Kick" and Buzz Navigation (Ceiling-Mounted).

Cranial Navigation consists of:

- Several software modules for registration, instrument handling, navigation and infrastructure tasks (main software: Cranial Navigation 4.1 including several components)

- IGS platforms (Curve Navigation 17700, Kick 2 Navigation Station, Buzz Navigation (Ceiling-Mounted) and predecessor models)
- Surgical instruments for navigation, patient referencing and registration

With this submission, several already existing features are now performed introducing a new algorithm using artificial intelligence and machine learning (AI/ML). This ML based functionality is used for the detection of inside-brain abnormities in T1-Weighted Contrast-Enhanced Magnetic Resonance (T1+C MR) volumetric images to allow a more convenient centering of the views and as an aid in the registration step (in surface matching) by allowing a pre-registration based on guide points. This pre-registration step is not mandatory. The AI/ML algorithm is a Convolutional Neuronal Network (CNN) developed using a Supervised Learning approach. The algorithm was developed using a controlled internal process that defines activities from the inspection of input data to the training and verification of the algorithm. The training process begins with the model observing, learning, and optimizing its parameters based on the training pool data. The model's prediction and performance are then evaluated against a test pool. The test pool data is set aside at the beginning of the project. This is a static algorithm (locked).

Automatic Registration iMRI is an accessory to Cranial Navigation enabling automatic image registration for intraoperatively acquired MR imaging. The registration object can be used in subsequent applications (e.g. Cranial Navigation 4.1). It consists of the software Automatic Registration iMRI 1.0, a registration matrix and a reference adapter.

Similarly, the ***Cranial EM System***, is an image-guided planning and navigation system to enable neurosurgical procedures. It offers instrument handling as well as patient registration to allow surgical navigation by using electromagnetic tracking technology.

It links patient anatomy (using a patient reference) and instruments in the real world or “patient space” to patient scan data or “image space”. This allows for the continuous localization of medical instruments and patient anatomy for medical interventions in cranial procedures. It uses the same software infrastructure components as the Cranial Navigation, and the software is also installed on IGS platforms consisting of a mobile monitor cart and an EM tracking unit. It consists of:

- Different software modules for instrument set up, registration and navigation (Main software: Cranial EM 1.1 including several components)
- EM IGS platforms (Curve Navigation 17700 and Kick 2 Navigation Station EM)
- Surgical instruments for navigation, patient referencing and registration

It uses the same artificial intelligence/machine learning algorithm as Cranial Navigation to support the registration step by allowing a pre-registration based on guide points/landmarks.

3. Substantial Equivalence

COMPARISON OF TECHNOLOGICAL CHARACTERISTICS WITH THE PREDICATE DEVICE

Cranial Navigation:

Characteristic	Primary Predicate K192703	Secondary Predicate K162929	Subject device
Indications for use	The Cranial IGS System, when used with a compatible navigation platform and compatible instrument accessories, is intended as an image-guided planning and navigation system to enable navigated surgery. It links instruments to a virtual computer image space on patient image data that is being processed by the navigation platform. The system is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, including: • Cranial Resection - Resection of tumors and other lesions - Resection of skull-base tumor or other lesions - AVM Resection • Cranial biopsies • Intracranial catheter placement • Intranasal structures and Paranasal Sinus Surgery - Functional endoscopic sinus surgery (FESS) - Revision & distorted anatomy surgery all intranasal structures and paranasal sinuses	The Stryker Navigation System, with the CranialMap software application, is intended as a planning and intraoperative guidance system to enable open or percutaneous computer assisted surgery. The system is indicated for any medical condition in which the use of computer-assisted planning and surgery may be appropriate. The system can be used for intraoperative guidance where a reference to a rigid anatomical structure can be identified. The system should be operated only by trained personnel such as surgeons and clinic staff. The system assists in the positioning of instruments for cranial procedures, including: - Cranial biopsies - Puncture of abscesses - Craniotomies - Craniectomies - Resection of tumors and other lesions - Removal of foreign objects - Skull base procedures - Transnasal neurosurgical procedures - Transphenoidal pituitary surgery - Shunt placement, including pediatric shunt placement	Compared to primary predicate same cranial resection indications. Craniofacial indications are newly added and are equivalent to the secondary predicate.

		- Placement of electrodes for recording, stimulation and lesion generation - Endoscopic Sinus Surgery (ESS) - Intranasal procedures - Ear implant procedures - Craniofacial procedures - Skull reconstruction procedures - Orbital cavity reconstruction procedures	
Mechanism of Action	Infrared tracking camera is recognizing infrared passive markers Instrument tracking in relation to the patients anatomy.	Active wireless optical tracking via infrared (IR) LED signal detection by the camera. Instrument tracking in relation to the patients anatomy.	Same as primary predicate, similar to secondary predicate device.
System accuracy	Mean navigation accuracy of ±2 mm and angular axis displacement of ±2^{o}	Mean navigation accuracy of ±2 mm and angular axis displacement of ±2^{o}	Same
Supported imaging modalities	CT, CTA, MR, MRA, US and PET	CT, CTA, MR, MRA, MRI, fMRI, DTI, PET and SPECT	Same as primary predicate and similar to secondary predicate
Programming language	C++ and C# (user interface)	C and C++	Similar to both, subject device uses HTML5 for GUI
Operating System	Microsoft Windows 7, Microsoft Windows 8.1	Windows XP Embedded (SPC 3.0) Windows 8.1 (SPC3.1) Off the shelf (OTS) Service Pack 3	Similar. Win 8.1 and Win10 are used to have latest technology.
Align views to view centroid with abnormity detection	Detection of abnormities based on an atlas of the human anatomy to allow a more convenient centering of views.	N/A	Compared to the primary predicate device, overall functionality is the same, but the abnormity is detected by an AI/ML based method. If not all requirements are met the previous detection based on an atlas of the human anatomy is used, as a fallback. Testing demonstrated that, both precision and recall of the ML-based method are higher in comparison to the atlas-based method. Thus, the change in functionality does not yield any new concerns regarding safety

			and effectiveness of the device.
Detection of anatomical landmarks/guide points	Detection of anatomical landmarks based on an atlas of the human anatomy.	N/A	Compared to the primary predicate device, overall functionality is the same, but landmarks (used for calculation of a pre-registration) are delivered by a AI/ML based method. Testing demonstrated there are no concerns regarding safety and effectiveness.
IGS Platforms	Curve, Kick and Buzz Navigation models are used, consisting of computer, touch monitor and IR camera.	The Stryker platform consists of a computer, a monitor, an IR camera, and IO -Tablet (input/output).	Similar to predicates. Modified and new platform models but with overall same design and operating principle.
Instruments	Instrumentation for patient referencing, registration and navigation. Compatible instruments from KLS Martin.	N/A	Same instrumentation. Former KLS Martin Instruments are now legally manufactured by Brainlab.

Accessory Automatic Registration iMRI:

Characteristic	Primary Predicate K192703	Subject device
Supported image modalities	MR	Same
Supported instruments	Optical standard pointer, Softouch, calibrated instrument	Similar. Subject device restricts support to optical standard pointer and the Softouch Pointer
Workflow steps	Data selection, registration calculation, verify result and adjustments if needed.	Same steps with updated GUI.
Hardware	Matrix and adapter	Similar matrix and adapter. Different design with same characteristics.
Structure	Functionality as a feature within the Cranial 3.1 application	Separate application as an accessory to the navigation.

Cranial EM System:

Characteristic	Third Predicate K213989	Subject device
Indications for use	Cranial EM is intended as an image-guided planning and navigation system to enable neurosurgery procedures.	Same

	The device is indicated for any medical condition in which a reference to a rigid anatomical structure can be identified relative to images (CT, CTA, X-Ray, MR, MRA and ultrasound) of the anatomy, such as: •Cranial Resection -Resection of tumors and other lesions -Resection of skull-base tumor or other lesions •Intracranial catheter placement	
Tracking technology	Electromagnetic tracking	Same
System accuracy	Mean navigation accuracy of ±2 mm and angular axis displacement of ±2°	Same
Functionality	Functionality for device set up, registration and navigation.	Same
Programming language	C++	Same
Detection of anatomical landmarks/guide points (in surface matching registration)	Detection of anatomical landmarks based on an atlas of the human anatomy.	Compared to the predicate device, overall functionality is the same, but landmarks (used for pre-registration) are delivered by an AI/ML based method. Testing demonstrated there are no concerns regarding safety and effectiveness.
EM IGS Platforms	Curve Navigation 17700 and Kick 2 Navigation Station EM	Same
Instruments	Instrumentation for patient referencing, registration and navigation. Compatible 3rd party instruments from KLS Martin.	Same instrumentation. Former KLS Martin Instruments are now legally manufactured by Brainlab.

4. Performance Data

The following testing was conducted on the Subject Device to establish substantial equivalence with the predicate devices:

Software Verification and Validation Testing

Software verification and validation testing were conducted and documentation was provided as recommended by FDA's Guidance for Industry and FDA Staff, "Guidance for the Content of Premarket Submissions for Software Contained in Medical Devices." This included product specifications, risk analysis or incremental test strategies. The software for this device was considered as a "major" level of concern.

For the two features now implemented using AI/ML (landmark detection in the pre-registration step and centering of views if no instrument is tracked to the detected abnormity), performance testing

comparing conventional to machine learning based landmark detection and abnormity detection were performed showing equivalent performance as in the predicate device.

Usability Evaluation

Summative usability was carried out according to the standard IEC 62366-1 “Medical devices – Part 1: Application of usability engineering to medical devices” in a simulated clinical environment for the new Craniofacial indication.

System accuracy testing

The positional and angular navigation accuracy for cranial procedures of the Subject Device including the software, the platforms and the instruments was evaluated considering a realistic clinical setup and representative worst case scenarios. The results show the following acceptance criteria are fulfilled:

- Mean Positional Error of the placed instrument’s tip ≤ 2 mm
- Mean Angular Error of the placed instrument’s axis ≤ 2°

Electrical safety and electromagnetic compatibility (EMC)

Compliance to electrical safety, RFID and EMC was evaluated on the Subject device according to the standards: IEC 60601-1, AIM 7351731 and IEC 60601-1-2.

Instruments

Instruments verification included:

- Biocompatibility assessment
- Cleaning and disinfection evaluation/reprocessing
- Mechanical properties of instruments
- Aging performance
- MRI testing (where applicable)

No clinical testing was needed for the Subject Device.

5. Conclusion

The comparison of the Subject Device with the predicate devices shows that Cranial Navigation and its accessory Automatic Registration iMRI and Cranial EM System have similar functionality, intended use and technological characteristics as the predicate device(s). Based on the comparison to the predicates and the performance testing conducted, the Subject Device is considered substantially equivalent to the predicate devices.