A report submitted in the fulfilment towards the successful completion of

Observation Student

(Internship)

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Introduction

Neuroelectrophysiology is a crucial branch of neuroscience that focuses on understanding the electrical activity of the nervous system. It plays a vital role in diagnosing and monitoring various neurological disorders by examining how neurons transmit electrical signals. These signals are essential for communication within the brain, spinal cord, and peripheral nervous system, which regulate movements, sensations, and overall bodily functions.

In neuroelectrophysiology, several important techniques are used to measure electrical activity. For instance, electroencephalography (EEG) records brain wave patterns, providing insights into brain function, while electromyography (EMG) and nerve conduction studies (NCS) examines how muscles and nerves interact. These techniques are not only important in clinical diagnosis but also in research for understanding brain and nerve functioning.

Nerve Conduction Study

Nerve Conduction Studies (NCS) assess the health of peripheral nerves by evaluating how quickly and effectively electrical signals travel through the nerve. This test is crucial for diagnosing conditions like diabetic neuropathy and sensory or motor nerve damage.

Device : **Nihon Koden.**

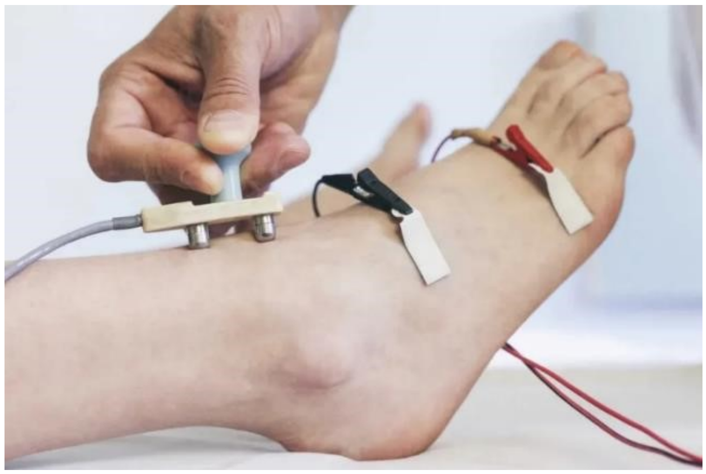

Fig-01: NCS Electrode and Stimulator

The system includes two surface electrodes, which are placed along the path of the nerve/muscle being tested, one is a recording electrode and the other is a reference electrode. The stimulators deliver controlled electrical impulses to stimulate the nerves, prompting them to generate signals. The stimulator contains anode and cathode electrode. These signals are then captured by the electrodes and transmitted to amplifiers which enhance the weak electrical signals for better clarity.

Once amplified, the amplified signals are converted from analog to digital format by an analog-to-digital converter (ADC) which gives precise and visual analysis. The processed data is displayed on the monitor. Distance between the proximal and ditsal point is meausred to calculate the nerve conduction velocity. Mark the onset latency, amplitude, motor velocity from the signal produced by the nerve. Nerve Conduction is conducted Bilaterally i. e, it is conducted for the right and left side of Upper and Lower Limb. It contains Motor and Sensory nerve conduction.

Motor Nerve Conduction:

Electrical current ranging from 0-30 mA for site 1(proximal), site 2(distal) and site 3(above distal), and the response is recorded as Compound Muscle Action Potential (CMAP).

CMAP: It stands for Compound Muscle Action Potential and refers to the electrical activity generated by a group of muscle fibers in response to the stimulation of their motor nerve. When a motor nerve is stimulated, it sends an electrical signal to the muscle it controls, causing the muscle to contract. The electrical activity generated by the muscle fibers during this contraction is recorded as CMAP.

Upper limb: It is conducted from the wrist to the elbow and above elbow, focusing on

1. Abductor Pollicis Brevis (APB) muscle - Median nerve
2. Abductor Digiti Minimi (ADM) muscle - Ulnar nerve
3. Extensor Indicis Proprius (EIP) muscle - Radial nerve

Lower limb: It is conducted from the ankle to fibula and above fibula, focusing on

1. Extensor Digitorum Brevis (EDB) muscle and Tibialis Anterior (TA) muscle - Common Peroneal Nerve (CPN)
2. Abductor Hallucis (AH) muscle - Posterior Tibial Nerve (PTN)
3.Fermoral muscle and nerve

Sensory Nerve Conduction:

A small electrical stimulus up to 30 mA is applied to distal point and proximal point, and the response called Sensory Nerve Action Potential (SNAP) is recorded.

SNAP: It is an electrical signal recorded from sensory nerves in response to stimulation. This potential reflects the health and function of sensory nerves, which are responsible for transmitting sensory information from the body to the brain.

Upper limb: It is conducted from the wrist to the elbow, focusing on,
1.Median nerve - Digit II on wrist
2.Ulnar nerve - Digit V on wrist
3.Radial nerve - Snuff box on forearm
4. Lateral Antebrachial Cutaneous (LABC) nerve - Lateral forearm on elbow
5. Medial antebrachial cutaneous (MABC) nerve - Medial forearm on elbow

Lower limb: It is conducted from the ankle to the fibular, focusing on
1.Superficial Peronral nerve – Lateral ankle
2.Saphenous merve – Medial ankle
3.Sural nerve – Posterior ankle
4.PTN (Medial Planter and Lateral Planter nerve) – Sole ankle

F-wave:
This is a late motor response used to assess proximal nerve conduction by applying the stimulus at the proximal point. It is primarily used for motor nerves.10 waves are recorded.

Upper Limb: It is conducted from the proximal point, focusing on,
1. Abductor Pollicis Brevis (APB) muscle - Median nerve
2. Abductor Digiti Minimi (ADM) muscle - Ulnar nerve

Lower Limb: It is conducted from the proximal point, focusing on,
1. Extensor Digitorum Brevis (EDB) muscle - Common Peroneal Nerve (CPN)
2.Abductor Hallucis (AH) muscle - Posterior Tibial Nerve (PTN)

H-reflex:

Involves testing nerve reflexes. It is tested at Tibial nerve in gastrocnemius(soleus) muscle at Lower limb.

<u>Observation</u>: In motor conduction, reduced amplitude of CMAP may indicate axonal damage. Increased latency may reflect demyelination A conduction block 50% drop in amplitude between site 1 (proximal) and site 2(distal) indicates a conduction.
In sensory conduction, abnormalities like reduced amplitude of SNAP indicate potential damage to the axonal damage. When no wave is detected, it suggests a complete loss of sensory function i.e, No SNAP.

Electroencephalogram (EEG)

An electroencephalogram (EEG) is a diagnostic tool used to measure and record the electrical activity of the brain. It detects abnormalities in brain function, such as sleep disorders, and seizures etc.

Device: **Nichon Kohden (Neurofax)** (64 channels), **Galileo NT** (32 Channels).

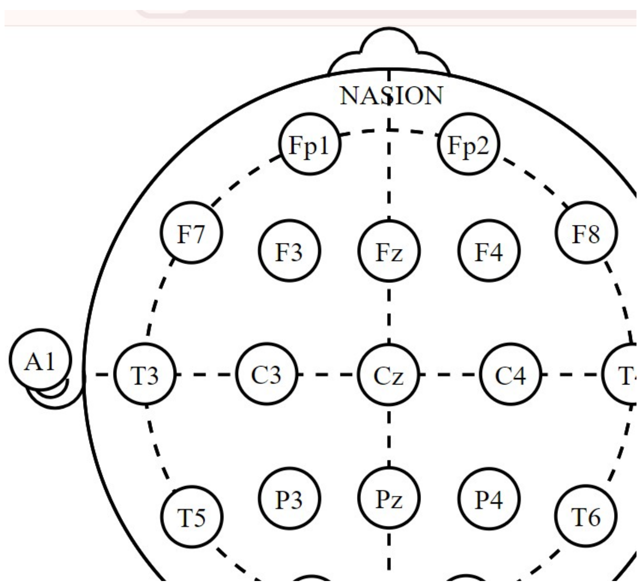

Fig-02: EEG Electrode Placement as per International 10-20

EEG electrodes are positioned on the scalp according to the 10-20 system, with odd-numbered electrodes on the left side and even-numbered electrodes on the right. This system refers to the distances between electrodes, which are 10% or 20% of the total head size. The nasion is the area at the top of the nose where it meets the forehead, and the inion is the prominent bump at the back of the head. Midline electrodes are placed as follows: Fz is positioned 10% of the distance from the forehead (nasion), Cz is located at the center of the head, and Pz is placed 20% from the back of the head (inion).

The frontal electrodes, Fp1 and Fp2, are positioned near the forehead, just above the eyebrows on the left and right, respectively. F7 and F8 are placed on the sides of the head, closer to the temples. The central electrodes, C3 and C4, are positioned above the ears, with C3 on the left and C4 on the right side of the head, directly opposite each other. The parietal electrodes, P3 and P4, are located behind C3 and C4, moving toward the back of the head. O1 and O2 are placed near the back of the head, closer to the inion. Temporal electrodes, T3 and T4, are positioned above each ear, and T5 and T6 are located behind T3 and T4, toward the back of the head. Lastly, A1 and A2 are reference electrodes placed above the ears.

Electrode impedance should be less than 5 kΩ to obtain accurate readings. An AC filter with a notch is used to eliminate electrical interference and noise. The machine's sensitivity is set to 14 µV per second, which is crucial for detecting brainwave patterns. The high filter is set to 70 Hz, and the sampling frequency is 2000 Hz for detailed signal capture. Proper earthing of electrodes is essential to ensure the accuracy of the recordings. It provides latency of 0.30 seconds. The frequency setting between brain wave lines is 10 kHz, capturing the electrical activity in real-time. Signals are recorded for a duration of 10 seconds per page.

The EEG records four main types of brain waves: alpha, beta, delta, and theta.

Alpha Waves (9-14Hz): Typically seen in awake adults, particularly when relaxed but alert.

Beta Waves (15-30Hz): Associated with active thinking and concentration.

Delta Waves (1-3Hz): Predominant in deep sleep, and sometimes seen in older adults.

Theta Waves (4-8Hz): Common in young children and during light sleep. Presence in awake adults or during sleep may indicate abnormalities.

Photostimulation that is a flashing light test is done to check for photo epilepsy (light-induced seizures). To assess wakeful brain activity, the patient's eyes are opened. During this time, alpha activity disappears. When the eyes are closed, alpha waves are seen in the occipital region, indicating a relaxed, wakeful state.

Observation: Apha waves are observed in posterior temporal, Posterior parietal and Occipital region (O1 and O2). When the patient is sleeping, we get sleep complex. Alpha waves are generally observed when the patient is awake and relaxed, while theta waves during sleep are considered normal. Irregular pattern can be indicated underlaying nerurological disorder. Presence of Alpha Waves During Sleep indicates abnormal activity. Theta waves are normal in children and during sleep, but their appearance in awake adults may indicate neurological issues.

Electromyogram (EMG)

An electromyogram (EMG) is a procedure that measures the electrical activity of muscles. It is used to detect muscle weakness, pain, and abnormal sensations in Nerves.

Device : **Nihon Koden.**

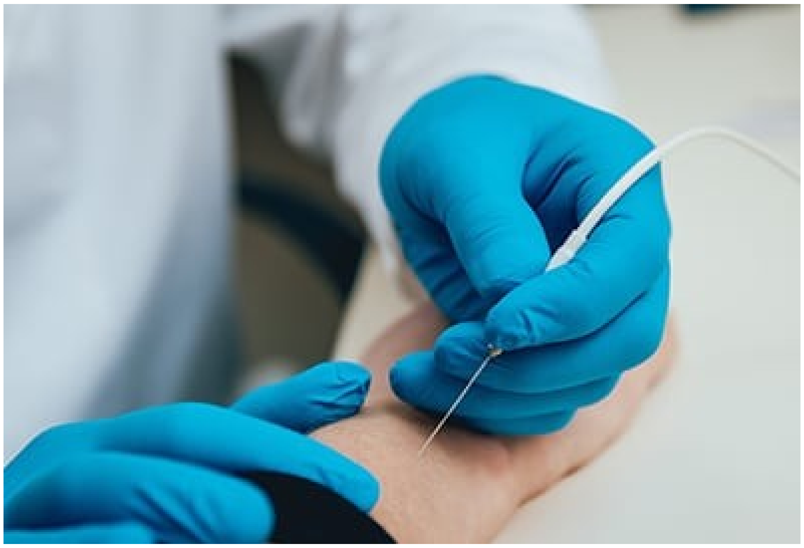

Fig-03: EMG Needle Placement

During the test, one small needle called electrode is inserted through the skin into the muscle. The electrical activity picked up by the electrodes is then displayed on an oscilloscope (a monitor that displays electrical activity in the form of waves). An audio-amplifier is used so the activity can be heard. EMG measures the electrical activity of the muscle during rest, slight contraction and forceful contraction. It is used to assess whether there is any spontaneous electrical activity when the muscle is at rest, activity that isn't present in healthy muscle tissue and the degree of activity when you slightly contract the muscle. The signal from the motor neuron is observed, and its sound can be heard. From this signal, we can detect abnormalities like:

- **Fibs**: Fibrillations are small, spontaneous discharges that occur without any voluntary muscle contraction. They are typically seen in muscles at rest, especially when there is nerve damage. They originate from individual muscle fibers, not from motor units. This means that when the motor neuron supplying a muscle is damaged or degenerates, the muscle fibers may become hypersensitive and fire on their own. Fibrillation potentials are irregular electrical signals that occur when muscle fibers aren't receiving proper nerve signals. They show up as regular, spontaneous spikes.
- **PSW**: PSW occur without voluntary muscle contraction and represent electrical activity from a single muscle fiber, much like fibrillations. They are seen in damaged muscles. PSW result from spontaneous depolarization of muscle fibers that have been denervated or damaged. The sharp initial deflection reflects the sudden depolarization of these fibers

The needle is used to check for any reflexes or spontaneous activity, and the signal is recorded to look for any issues.

Intraoperative Neurophysiological Monitoring (IONM)

Intraoperative Neurophysiological Monitoring (IONM) is a critical technique used during surgeries to monitor the functional integrity of neural pathways in real-time. It helps surgeons avoid potential damage to the nervous system by providing continuous feedback about the electrical activity of nerves, muscles, and the spinal cord. IONM is particularly valuable during complex procedures like spine surgeries, brain surgeries, or operations near major nerves.

Machine used is from **Medtronic NIM Eclipse**.

Fig-04: NIM Monitering

IONM monitoring is used in cases such as IDEM, Tumor, trigeminal, detehering and major spinal cord and brain cases.

Electrodes:

Corkscrew Elecrode:

The corkscrew shape electrode is designed in cork shape with screw kind of fixature to stimulate and record response to and from the scalp.

Fig-05: Corkscrew Electrode

Needle Monopolar Electrode:

The needle monopolar electrode is a single contact electrode.

Fig-06: Needle Monoploar Electrode

Needle Bipolar Electrode:

A needle bipolar electrode has active and reference electrode it is placed in muscle belly which is being recorded.

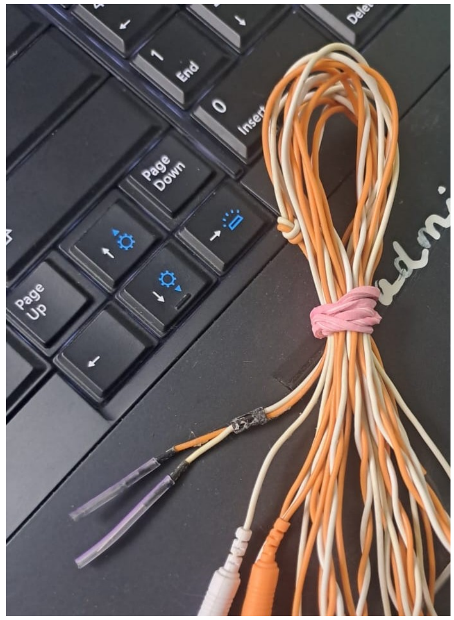

Fig-07: Needle Bipoloar Electrode

Grid Electrode:

A Grid Electrode is a specialized electrodes used for recording electrical activity from the cortex of brain. It's a flat, grid-like arrangement of multiple conductive contacts.

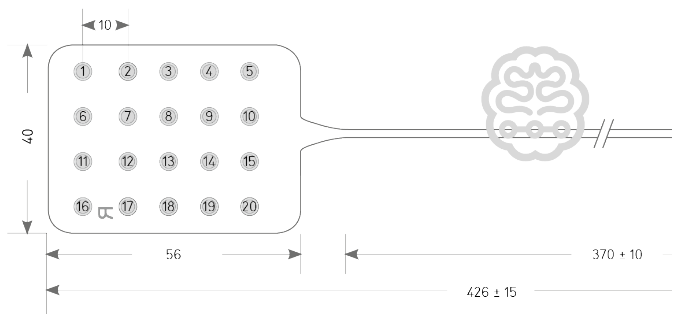

Fig-08: 4x5 Grid Electode

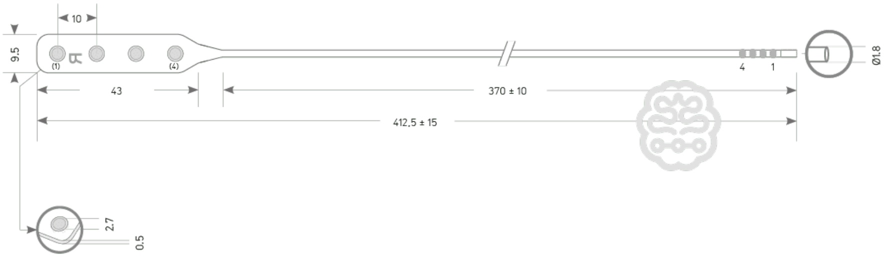

Fig-09: 1x4 Grid Electrode

<u>Stimulator:</u>

<u>Monopolar Stimulator:</u>

A monopolar stimulator consists of a single active electrode that delivers electrical stimuli to the target tissue.

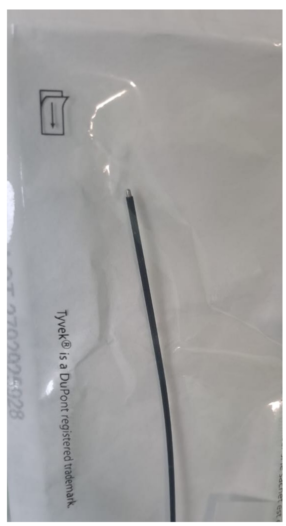

Fig-10: Monoploar Stimulator

<u>Ball Point Stimulator:</u>

A ball-point stimulator has a rounded, ball-shaped tip electrode.

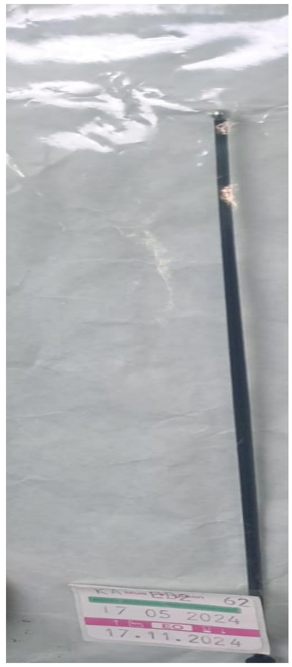

Fig-11: Ball point Stimulator

Bipolar Stimulator:

A bipolar stimulator consists of two closely spaced electrodes (one positive and one negative) that deliver electrical stimuli between them.

Fig-12: Bipolar Stimulator

Coaxial Stimulator:

Coaxial stimulator consists of two concentric electrodes: a central active electrode and an outer ring-shaped reference electrode that surrounds the active electrode both the electrode is aligned along the same axis.

Fig-13: Coaxial Stimulator

Procedure:

Somatosensory Evoked Potentials (SSEPs)

SSEPs are used to assess the integrity of sensory pathways. Electrical stimulation is applied to peripheral nerves, such as the Medial nerve in Upper limb and Tibial nerve in Lower limb. The electrical signal travels through the sensory pathways up to the somatosensory cortex, where it is recorded using scalp electrodes, such as corkscrew electrodes. It is used to ensure no disruption to the sensory pathways during surgical manipulation. Scalp electrodes (corkscrew) are placed to record the cortical responses.

Motor Evoked Potentials (MEP)

MEPs are recorded to monitor the integrity of motor pathways. These are obtained by stimulating the motor cortex with recordings from muscles through needle electrodes. The procedure assesses the corticospinal tract function, responsible for voluntary motor control. Initial Baseline readings are taken to establish a baseline muscle activity level. It is used to prevent damage to motor pathways, ensuring motor function remains intact.

Electromyogram (EMG)

EMG is used to monitor the function of motor neurons and detect nerve damage during surgery. The needle electrodes are placed on muscles that are innervated by the nerves of interest. Direct stimulation is done using Stimulator.

Observation:

Baseline readings for Somatosensory Evoked Potentials (SSEP), Motor Evoked Potentials (MEP), and Electromyography (EMG) are established before the surgery begins to provide a reference for normal neural function.

Changes in amplitude of the SSEP signals during surgery indicate potential sensory pathway injury, alerting the surgical team to possible nerve compromise and prompting immediate evaluation.

Any significant reduction in the amplitude of MEP signals suggests possible motor pathway compromise, which allows the surgeon to adjust the surgical procedure accordingly to prevent lasting motor deficits.

Any response from the stimulating area indicates the presence of nerve roots or nerve tracts in the operating region, providing crucial information about the functional integrity of nearby nerves and guiding surgical interventions.

This comprehensive monitoring helps ensure the safety and effectiveness of surgeries involving critical neural structures.

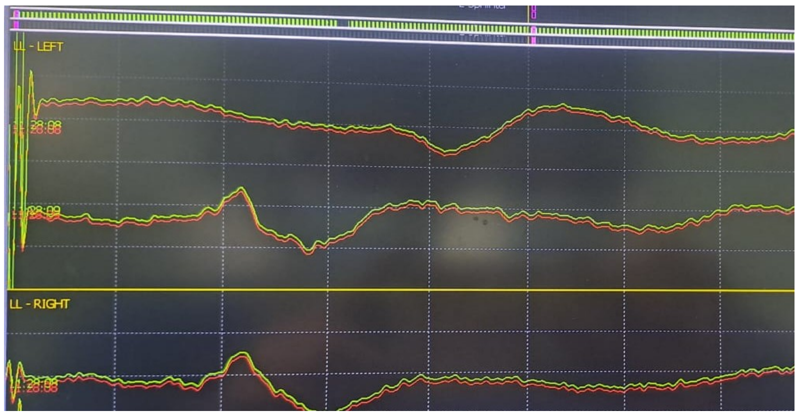

Fig-14: SEEP Baseline Reading

Fig-15: MEP Baseline Reading

Electrocorticogram (ECoG)

An electrocorticogram (ECoG) is a type of brain recording technique where electrodes are placed directly on the surface of the brain (the cerebral cortex) to measure electrical activity. It has similar IONM procedure as the SSEP, EMG and MEP.

ECoG is used for monitoring during the removal of a tumor in the brain and it is done for patient with epilepsy, brain tumor etc.

Grid electrode is placed directly on the surface of the cortex to record electrical activity from the cerebral cortex. A craniotomy is required to implant the grid electrode. These electrodes can vary in size and configuration depending on the region being examined. There is 4x5 and 1×4 etc grid electrode

EcoG is used in mapping regions responsible for specific functions like movement, language, and sensory processing in brain. It helps to avoid damaging critical areas.

Observation: These are sharp waves or spikes in brain activity that indicate abnormalities in hyperactive neural regions. In patients with brain tumors, ECoG can detect abnormal electrical activity surrounding the tumour.

Summary

Electroneurophysiology is a branch of biomedical engineering focused on studying the electrical activities of the nervous system, encompassing various techniques such as Nerve Conduction Studies (NCS), Electroencephalography (EEG), Electromyography (EMG), Intraoperative Neurophysiological Monitoring (IONM), and Electrocorticography (ECoG). NCS evaluates the function of peripheral nerves by measuring the speed and strength of electrical signals as they travel along the nerves. This technique helps diagnose conditions like neuropathy and other nerve-related disorders. EEG records electrical activity in the brain through electrodes placed on the scalp. It is essential for diagnosing epilepsy, sleep disorders, and brain function monitoring during surgeries. EMG measures the electrical activity of muscles during rest and contraction, aiding in the diagnosis of neuromuscular disorders.

IONM is a critical technique employed during surgical procedures, particularly spinal and brain surgeries, to monitor the integrity of neural pathways in real time. By detecting potential complications during surgery, IONM helps prevent nerve deficits during the surgery. EcoG involves placing electrodes directly on the surface of the brain it provides high-resolution data on cortical activity and is often used in epilepsy surgery to localize seizure foci. Together, these electroneurophysiological techniques form a comprehensive approach to understanding and diagnosing neurological conditions, facilitating timely and effective interventions in clinical settings. Their integration into both diagnostic and intraoperative environments underscores their significance in enhancing patient care and optimizing surgical outcomes.