Adequacy of Anesthesia Concept

Unique clinical measurements for precise anesthesia delivery

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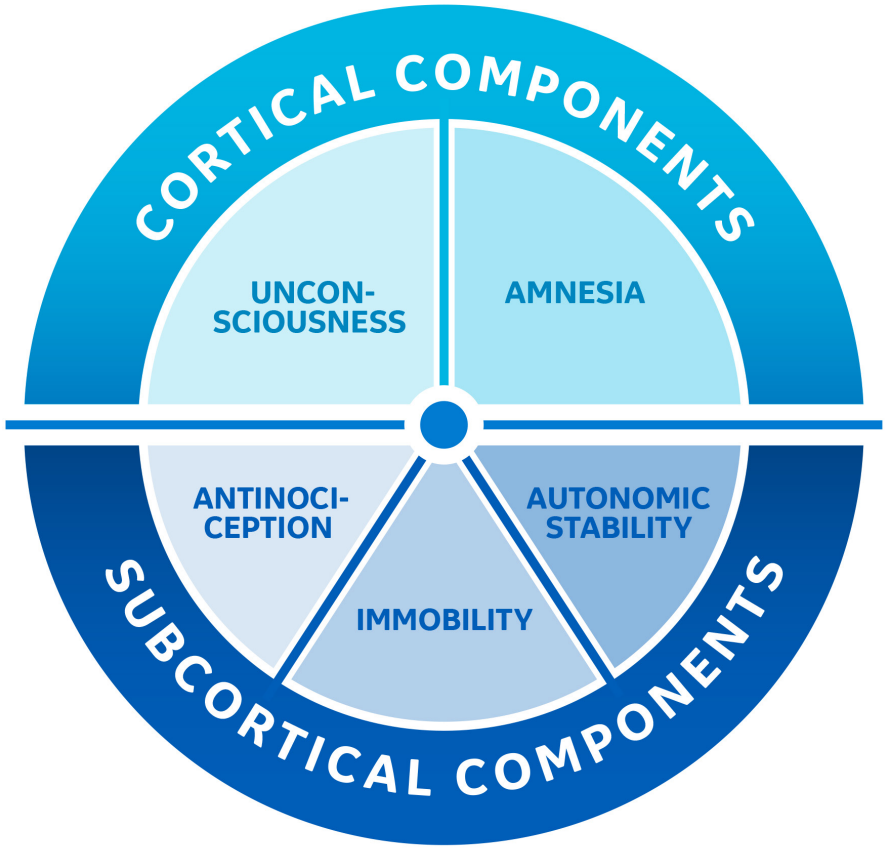
NOTE: This brochure contains information about SPI, which is not cleared for use in the US or Japan.

Adequacy of Anesthesia

Helping clinicians deliver precise anesthesia

Adequacy of Anesthesia (AoA) is a concept consisting of various unique parameters to help you assess a patient's response to the delivery of inhaled and intravenous hypnotics, opioids, other analgesic drugs as well as neuromuscular blocking agents during general anesthesia.

The two components of Adequacy of Anesthesia are listed below.



Cortical components

Unconsciousness refers to the lack of awareness of the outside world. It is this component where the patient is asleep during general anesthesia.

Amnesia refers to the patient's loss of memory of the operation. It is imperative that the patient does not have any memory recollections of the events during the operation.

Subcortical components

Antinociception refers to inhibition of the nociceptive processing in the nervous system. Analgesia is the treatment to provide antinociception.

Immobility refers to the patient's lack of motion. Complete immobility should be ensured to maintain a stable surgical field.

Autonomic stability refers to the absence of excessive hemodynamic responses. Anesthesia impacts hemodynamic stability, therefore, close monitoring is needed to help maintain balance.

GE Healthcare's unique parameters provide continuous measurements for each of these components:

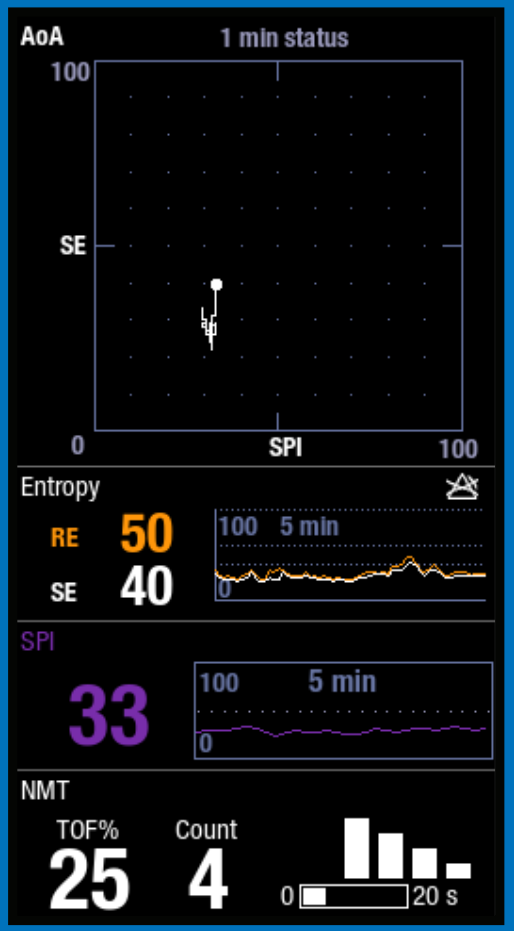
- Level of consciousness and amnesia with **Entropy**™
- Patient's response to surgical stimuli (nociception) and analgesic medications (antinocipeption) with **Surgical Pleth Index (SPI**™[1]**)**
- Muscle relaxation and immobility with neuromuscular transmission **(NMT)**
- Autonomic stability with hemodynamic parameters

GE Healthcare offers a holistic view of the patient's response to anesthesia with its AoA split-screen on the CARESCAPE™ monitor. The monitor displays values and trends obtained from parameter modules for SPI, Entropy (State Entropy SE, Response Entropy RE and burst suppression ratio) and neuromuscular transmission (NMT).

The monitor's BalanceView feature provides clear visualization of the patient's response to changes in anesthesia conditions, enabling the anesthesiologist to adjust the analgesic levels and optimize patient consciousness to the desired level. Inadequate hypnosis or analgesia level is signaled when the white dot moves away from the target zone.

1. SPI is not FDA cleared and is not available in the U.S.
2. Wennervirta, J. *et al*. Surgical stress index as a measure of nociception/antinociception balance during general anesthesia. *Acta Anaesthesiol Scand* **52(8)**, 1038–45 (2008).
3. Gruenewald, J. *et al*. Influence of different remifentanil concentrations on the performance of the surgical stress index to detect a standardized painful stimulus during sevoflurane anesthesia. *Br J Anaesth* **103(4)**, 586-93 (2009).

CARESCAPE Monitor's BalanceView Feature



SPI is a measurement of the nociception-antinociception balance.

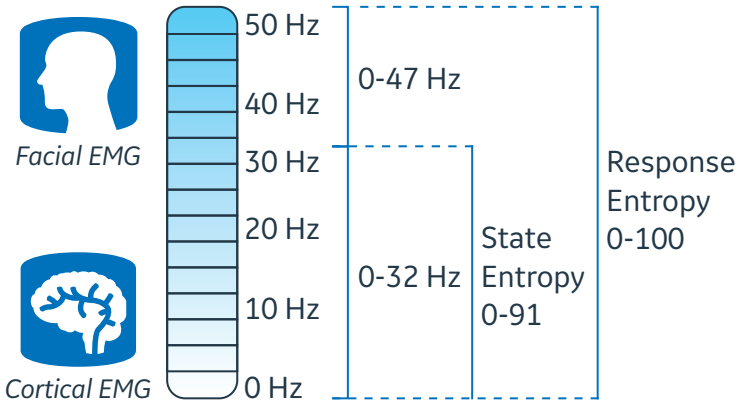
Clinical evidence suggests an SPI target range of 20 to 50.[2,3]

Entropy

The Entropy measurement is captured with the E-ENTROPY module and accessories. Cleared for adult and pediatric patients older than 2 years, data is collected from the electroencephalograph (EEG) and frontal electromyograph (FEMG) signals during general anesthesia. The spectral entropies, Response Entropy (RE) and State Entropy (SE), are processed EEG and FEMG variables, indicating the level of awareness and possible emergence from anesthesia.

Entropy monitoring provides two indexes:

- Response Entropy (RE) is sensitive to the activation of facial muscles (i.e., FEMG). Its response time is very fast; less than two seconds. FEMG is especially active during the awake state, but may also activate during surgery in response to surgical stimuli. Facial muscles may also give an early indication of emergence, and this can be seen as a quick rise in RE.
- State Entropy (SE) is a steady and robust signal. The SE value is always less than or equal to RE. The estimation of the hypnotic effect of anesthetic drugs on the brain during general anesthesia may be based on the SE value. SE is not affected by sudden reactions to the facial muscles because it is based on the EEG signal and is less affected by neuromuscular blockade.



SE varies between 0 (deep anesthesia) to 91 (awake).

RE varies between 0 (deep anesthesia) to 100 (awake/moving).

The recommended range during general anesthesia for both RE and SE is from 40-60 and, therefore, a decrease of SE below 40 may indicate an unnecessarily deep anesthesia while an increase above 60 may indicate the need for adjusted tritation for deeper hypnosis.

The Entropy measurement is to be used as an adjunct to other physiological parameters such as the EEG waveform signal which can help for in depth and more comprehensive analysis of the state of the brain.

In patients older than two years-old, RE and SE may be used as an aid in monitoring the effects of certain anesthetic agents, which may help the user titrate anesthetic drugs (inhaled and intravenous hypnotics) according to the patient's individual needs. Furthermore, the use of Entropy parameters may be associated with a reduction of anesthetic drugs consumption and faster emergence from anesthesia. Studies have shown that such optimization leads to a significant reduction in the consumption of anesthetic agents (*see* Figures 1 and 2) as well as fastened emergence. Additionally, Gruenewald et al. have seen that propofol-remifentanil Entropy-guided anesthesia may lead to a lower frequency of hemodynamic unwanted events such as hypertension/hypotension, tachycardia and bradycardia (*see* Figure 3).

Entropy helps address some important challenges of anesthesia care. A study by Cleveland Clinic of 9,000 patients found that clinically important hypotension occurred in 42% of the patients and was significantly associated with 30-day myocardial infarction, acute kidney injury and mortality.[4] Another study by Musialowicz et al. determined that unnecessarily deep levels of anesthesia are commonly used and that this is a risk factor for intraoperative hypotension.[5] Additionally, Entropy may help avoid unnecessarily deep states of hypnosis, including burst suppression that has been associated with increased risk of delirium.[6]

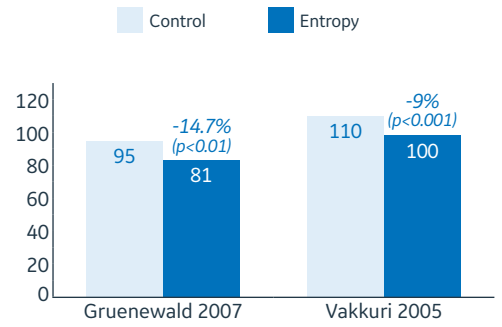


Figure 1: Propofol consumption µg/kg/min.[1]

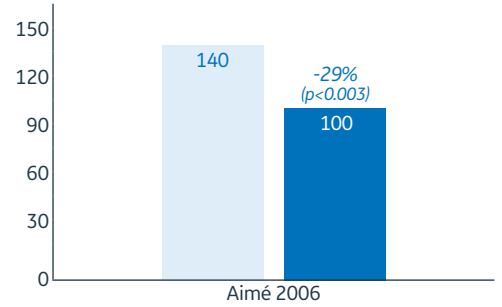


Figure 2: Sevoflurane consumption mg/kg/hr.[2]

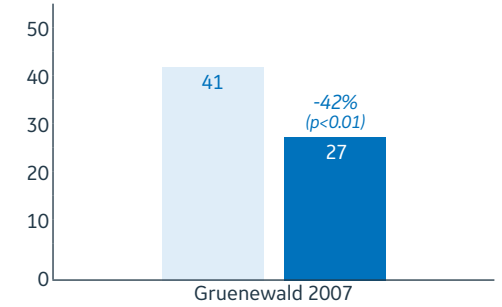


Figure 3: Number of hemodynamic events.[3]

1. Gruenewald M. *et al.* M-Entropy guidance vs. Standard Practice during propofol-remifentanil anesthesia: a randomised controlled trial. *Anesthesia* **62(12)**, 1224-9 (Dec 2007).
2. Vakkuri A. *et al.* Spectral Entropy Monitoring Is Associated with Reduced Propofol Use and Faster Emergence in Propofol–Nitrous Oxide–Alfentanil Anesthesia *Anesthesiology* **103**, 274–9 (2005).
3. Aime I. *et al.* Does Monitoring Bispectral Index or Spectral Entropy Reduce Sevoflurane Use? *Anesth Analg* **103**, 1469 –77 (2006).
4. Sessler D. *et al.* Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death: A Substudy of the POISE-2 Trial *Anesthesiology* **128(2)**, 317-327.(Feb 2018).
5. Musialowicz, T. and Lahtinen, P. Current Status of EEG-Based Depth-of-Consciousness Monitoring During General Anesthesia. *Curr Anesthesiol Rep* **4**, 251–260 (2014).
6. Daiello LA, *et al.*, Postoperative Delirium and Postoperative Cognitive Dysfunction: Overlap and Divergence. *Anesthesiology* **131(3)**, 477-491 (Sep 2019).

Surgical Pleth Index (SPI)

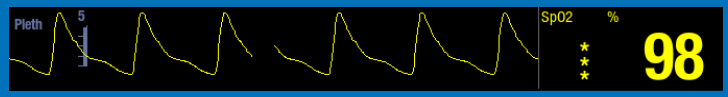
SPI is indicated for monitoring the patient's response to surgical stimuli and analgesic medications in unconscious and fully anesthetized adults over 18 years of age. SPI is a physiologic parameter derived from hemodynamic information in the photoplethysmographic waveform obtained from a patient's finger using GE Healthcare's TruSignal™ SpO_2 technology. It is to be used as an adjunct to other physiological parameters.

By observing the SPI value and trend, clinicians can monitor real time adult patient's responses to surgical stimuli and analgesic medications, therefore saving valuable time and optimizing analgesia delivery.

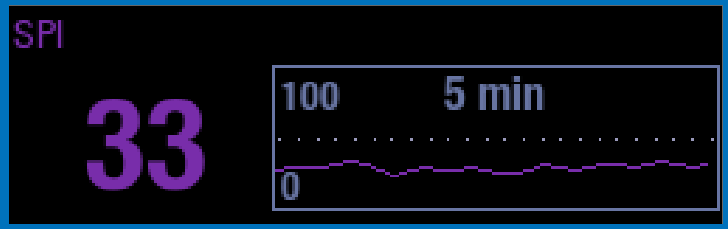
The optimal SPI target has not been recommended yet as more studies need to prove the clinically relevant range of SPI measurements. However, in several studies, a range of [20; 50] has been considered for guiding analgesic medicine titration.[1,2]

SPI may represent the balance between nociception and antinociception and as such, the variation from its baseline is another critical element to consider. Gruenewald et al.[3] demonstrated that an increase in SPI of 10 was found to be the threshold for movement in patients receiving low remifentanil dosage. It may be reasonable to assume that if SPI increases from baseline by 10 or more during surgical stimulation an inadequate analgesia level can be present. Further clinical validation is needed to validate these preliminary findings.

1. Chen, X. *et al*. Comparison of surgical stress index-guided analgesia with standard clinical practice during routine general anesthesia: a pilot study. *Anesthesiology* **112**, 1175–83 (2010).
2. Wennervirta, J. *et al*. Surgical stress index as a measure of nociception/antinociception balance during general anesthesia. *Acta Anaesthesiol Scand* **52(8)**, 1038–45 (2008).
3. Gruenewald, J. *et al*. Influence of different remifentanil concentrations on the performance of the surgical stress index to detect a standardized painful stimulus during sevoflurane anesthesia. *Br J Anaesth* **103(4)**, 586-93 (2009).



SPI is calculated from the beat-to-beat pulse rate variation (PR) and the plethysmogram amplitude (PPGA).

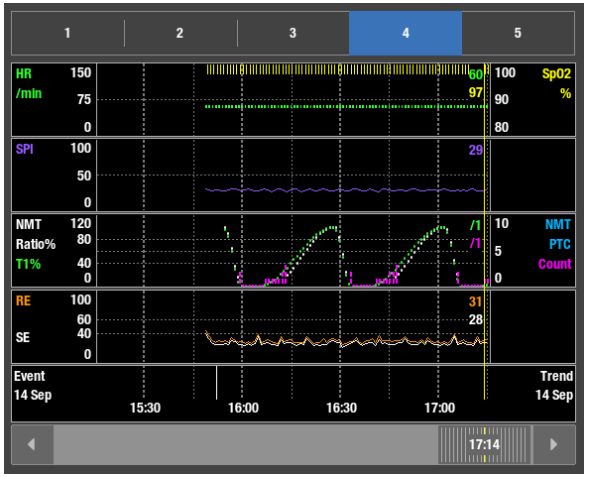


SPI varies between 0 (no reactivity) to 100 (high reactivity).

Chen et al.[4] compared SPI-guided analgesia to standard clinical practice and concluded that SPI-guided remifentanil titration resulted in a significant reduction of opioids consumption and reduced incidence of unwanted events such as hypertension, hypotension, tachycardia and movement during surgery (Figures 4 and 5). Further, SPI showed the highest prediction probability when compared to other common variables (HR, MAP, BIS) for indicating maximum stimulation during surgery.

Bergmann et. al. also demonstrated that SPI-guided remifentanil titration, additional to the already given maximal sufentanil concentration, seemed to result in much lower rate of adverse hemodynamic events during sternotomy and sternal spread. SPI seemed to help finding the specific patient additional remifentanil dose without substantial risk of hyperalgesia.[6]

The study from Funcke et al. with sufentanil analgesic drug showed SPI-guided titration was associated with a reduced endocrine stress response.[7] The study also states that using SPI leads to better timing of titration of analgesia and a more balanced state of the patient.[7]



Patient case screenshot: All AoA parameters indicate patient in a steady state.

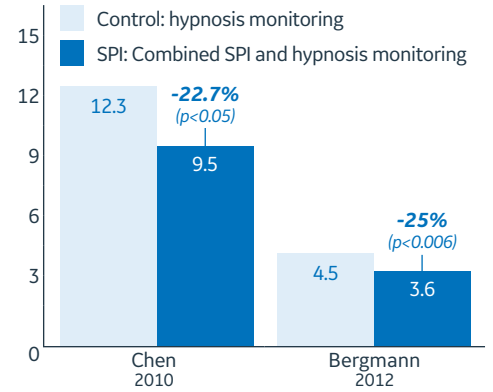


Figure 4: Remifentanil consumption µg/kg/hr.[5]

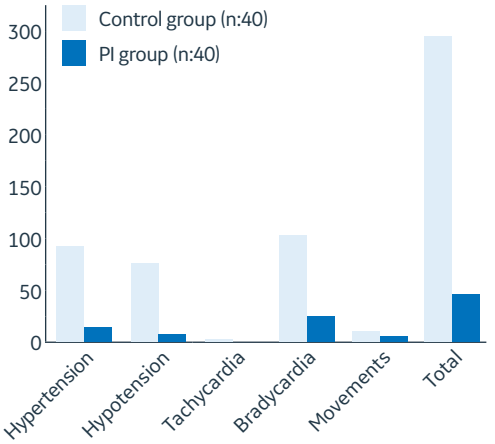


Figure 5: Number of unwanted events during general anesthesia.[8]

4. Chen, X. *et al*. Comparison of Surgical Stress Index-guided Analgesia with Standard Clinical Practice during Routine General Anesthesia. Anesthesiology **112**, 1175– 83 (2010).
5. Bergmann, I. *et al*. Surgical pleth index-guided remifentanil administration reduces remifentanil and propofol consumption and shortens recovery times in outpatient anesthesia. *Br J Anaesth* **110(4)**, 622-8 (2013).
6. Bergmann, I. *et al*. Remifentanil added to sufentanil-sevoflurane Anesthesia suppresses hemodynamic and metabolic stress responses to intense surgical stimuli more effectively than high-dose sufentanilsevoflurane alone. *BMC Anesthesiology* **15(1)**; 3 (2015).
7. Funcke S. *et al*. Nociception level-guided opioid administration in radical retropubic prostatectomy: a randomised controlled trial, *Br J Anaesth*, **126(2)**, 516-524 (Feb 2021).
8. Chen, X. *et al*. Comparison of surgical stress index-guided analgesia with standard clinical practice during routine general anesthesia: a pilot study. *Anesthesiology* **112**, 1175–83 (2013)

Quantitative neuromuscular transmission monitoring gives a clear picture of the individual dosage needs and facilitates optimal administration of neuromuscular blocking agents and antagonists.

Neuromuscular Transmission (NMT)

Electromyography (EMG) uses the ElectroSensor and records the electrical muscular fibers activity in response to ulnar nerve stimulation.

Kinemyography (KMG) uses the mechanosensor and quantifies the evoked mechanical response by measuring the motion of the thumb by a piezoelectric sensor, which converts the physical motion into an electrical signal.

Postoperative residual curarization (PORC) incidences in post-anesthesia care units are estimated to be approximately 40%.[1] Such residual effects (even at levels of recovery as high as a TOF ratio of 0.7-0.8) have clinical consequences and complications that can prolong hospitalization. Current recommendations advocate the use of short- or intermediate-acting NMBAs, routine reversal of neuromuscular block, and quantitative monitoring of the neuromuscular function whenever relaxants are used, especially before and after reversal.[2,3]

Adequate recovery from neuromuscular block, indicated by TOF ratio>0.9, can be reliably determined only with a quantitative measurement. EMG TOF ratio is an alternative gold standard, after mechanomyography (MMG), for detecting neuromuscular block in clinical setting and is not interchangeable with acceleromyography (AMG) TOF.[4] Liang et al. demonstrated that AMG overestimates recovery by at least 0.15. Therefore, residual neuromuscular block, defined as an EMG or MMG TOF ratio of <0.90, cannot be excluded immediately on reaching an AMG TOF ratio of 0.90 or indeed 1.00.[4]

Studies have shown that the implementation of quantitative EMG neuromuscular monitoring resulted in a significant reduction in the incidence of incompletely reversed patients in the PACU.[5] In addition, a cohort study concluded that residual neuromuscular blockade contributed to the development of critical respiratory events during PACU stays and recommends routine quantitative neuromuscular monitoring to help reduce these events.[6]

Possible Consequences of Residual Paralysis[5,7,8]

- Increased post-operative complications, mortality and morbidity
- Increased length of hospital stay
- Potential patient distress
- Risk of critical respiratory events in post-anesthesia care
- Reintubation

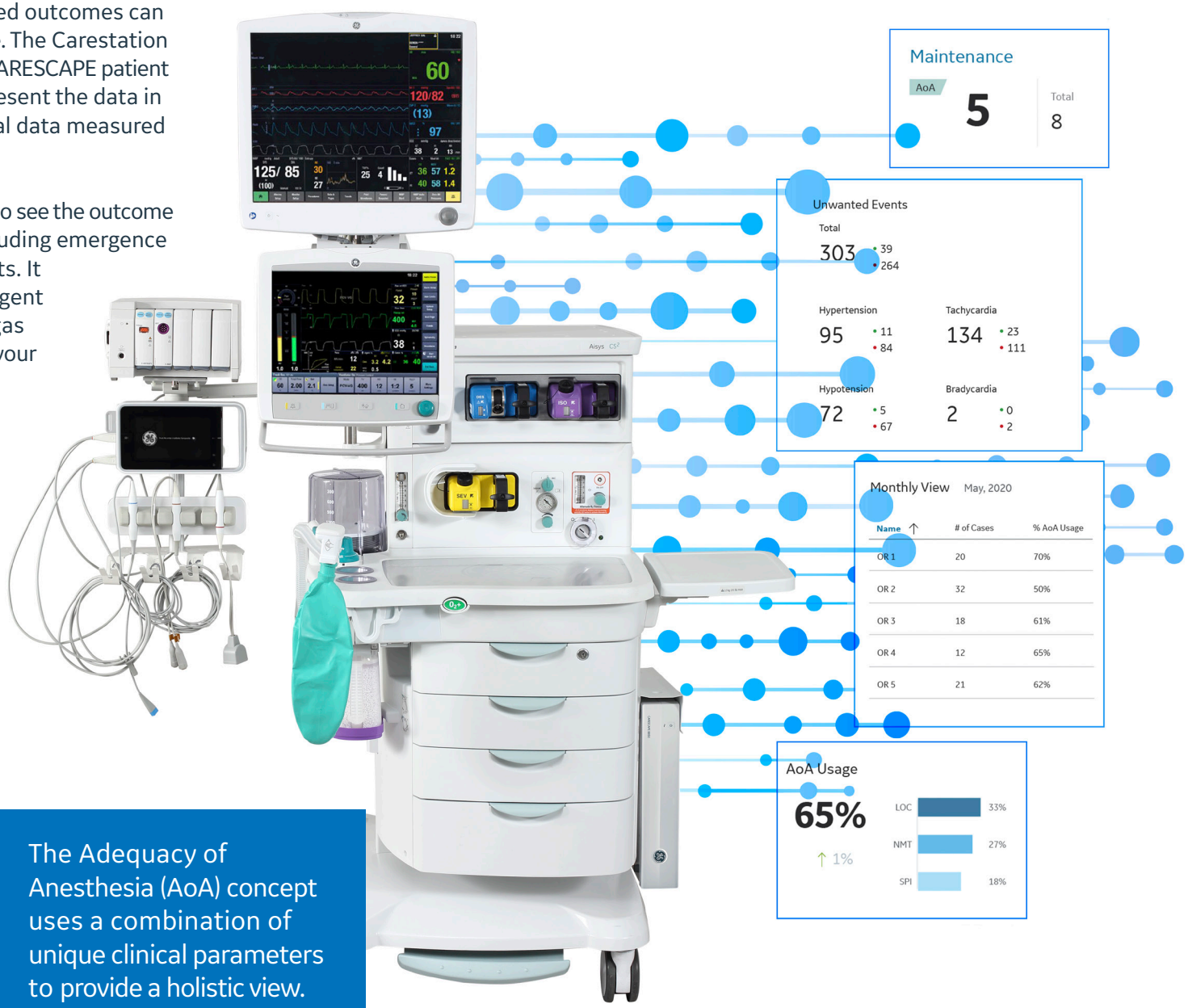
1. Murphy G. and Brull S. Residual neuromuscular block: lessons unlearned. Part I: definitions, incidence, and adverse physiologic effects of residual neuromuscular block. *Anesth Analg* **111(1)**, :120-8 (Jul 2010).
2. Murphy G. and Brull S. Residual neuromuscular block: lessons unlearned. Part II: methods to reduce the risk of residual weakness. *Anesth. Analg*. **111(1)**, 129-40 (Jul 2010).
3. Miller R. and Ward T. Monitoring and pharmacologic reversal of a nondepolarizing neuromuscular blockade should be routine. *Anesth. Analg*. **111(1)**, 3-5 (Jul 2010).
4. Liang S. *et al.* An ipsilateral comparison of acceleromyography and electromyography during recovery from nondepolarizing neuromuscular block under general anesthesia in humans. *Anesth Analgesia* **117(2)**, 373-9 (Aug 2013).
5. Todd M. *et al.* The implementation of quantitative electromyographic neuromuscular monitoring in an academic anesthesia department. *Anesth Analg*. **119(2)**, 323-31 (Aug 2014).
6. Faraj K *et al.* The association between residual neuromuscular blockade (RNMB) and critical respiratory events: a prospective cohort study. *Perioper Med* **10(1)**, 14 (May 2021).
7. Benoît P. *et al.* Residual Paralysis after Emergence from Anesthesia, *Anesthesiology* 1013-1022 (2010).
8. Blobner M. *et al.* Safe and Efficient Anesthesia: The Role of Quantitative Neuromuscular Monitoring. Advances in Patient Safety

Adequacy of Anesthesia (AoA) Application[1]

Providing insights to AoA protocol adherence

Understanding the practice of AoA and associated outcomes can be unnecessarily challenging and labor intensive. The Carestation Insights AoA application combines data from the CARESCAPE patient monitors and Aisys™[2] anesthesia machines to present the data in an intuitive way, showing real time[3] and historical data measured against customized performance targets.

The application's analysis view provides the ability to see the outcome information associated with the use of AoA, including emergence times, agent costs, and certain unwanted events. It also includes the capability to track anesthetic agent costs and provide visualization of greenhouse gas emissions of anesthetic drugs, helping you meet your financial and environmental goals.



Outcomes

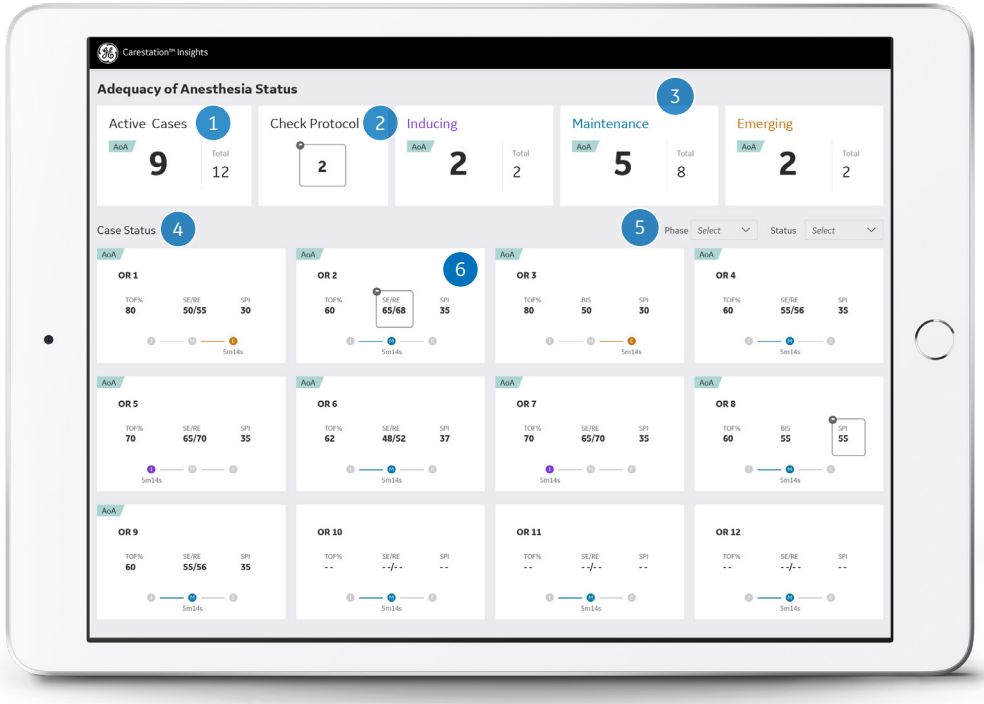
- Gain clinical insights from patient outcome information associated with AoA protocol adherence
- Optimize AoA practices to help reduce variability across multiple ORs
- Analyze anesthetic agent use, cost and environmental impact

The Adequacy of Anesthesia (AoA) concept uses a combination of unique clinical parameters to provide a holistic view.

1. This product is in development. Depictions of the application are illustrative, subject to change, and may not be representative of the final product. Please contact your GE Healthcare representative for updates.
2. Available with Aisys CS2 anesthesia machines v11.X and higher.
3. Actual time may vary slightly due to hospital network and processing times.

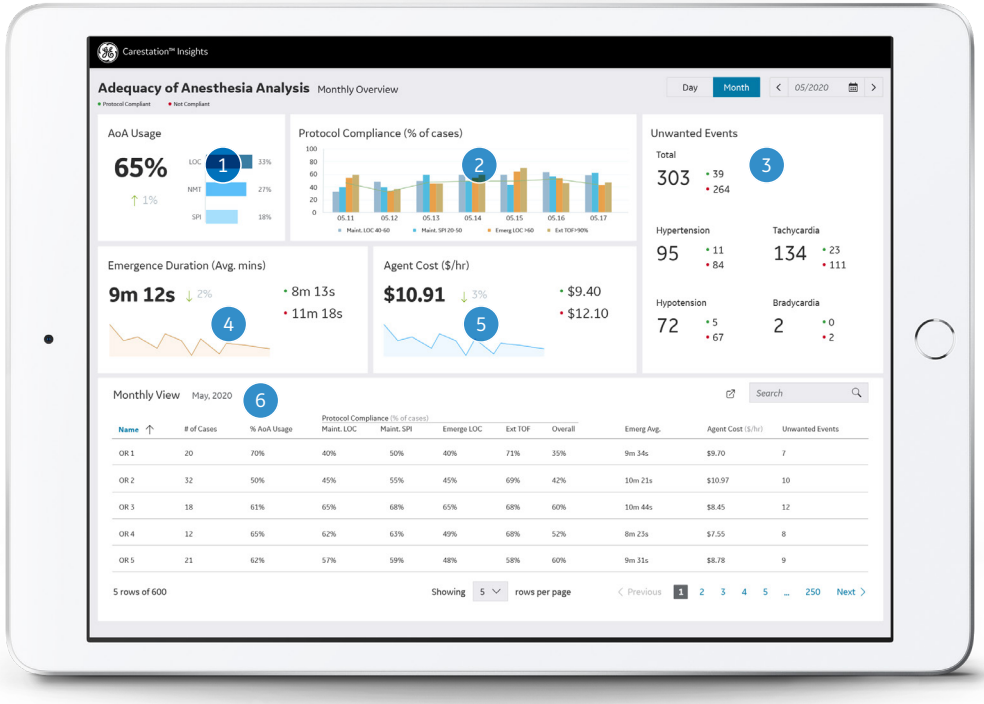
Operating Room Status: Live view into OR case phase

1. Total active cases and number of cases using AoA protocols.
2. Number of protocols currently out of compliance.
3. Dashboard of total cases by anesthesia phase, and cases using AoA protocols.
4. Dashboard of all active cases using AoA.
5. Filter cases by phase or status.
6. Specific OR details at a glance. Out of compliance protocols will be denoted with a box.



Operating Room Analysis: OR AoA practice and events overview

1. View AoA usage across all ORs and by parameter.
2. See AoA protocol compliance over time, based on targets and ranges set in the application configuration.
3. Number of unwanted events by type.
4. Average emergence time across all cases for the timeframe.
5. Average cost of anesthetic agents used across all cases.
6. Specific OR details by date – click to drill down to OR level details.



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For more information about Adequacy of Anesthesia, please visit clinicalview.gehealthcare.com

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