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BRAINSCOPE®

**2017 North American Traumatic
Brain Injury Assessment Solutions
New Product Innovation Award**

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BEST
2017 PRACTICES
AWARD

**NORTH AMERICAN TRAUMATIC
BRAIN INJURY ASSESSMENT SOLUTIONS
NEW PRODUCT INNOVATION AWARD**

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Industry Challenges

According to the Centers for Disease Control (CDC), traumatic brain injury (TBI) is a major cause of death and disability in the United States (US), which accounts for about 30% of all injury-related deaths¹. Approximately 153 people die in the US daily from TBI and survivors can face many symptoms—including cognition, movement, emotional, or sensational impairment—lasting anywhere from a few days to the rest of their lives². TBI can be caused by a powerful bump, jolt, or blow that disrupts normal brain function and can range from mild to severe. Mild TBIs are also referred to as concussions and are the most common TBI³. According to the CDC, there were about 2.8 million TBI-related emergency room visits, hospitalizations, and deaths in the US in 2013¹. This number doesn't include patients who were evaluated for TBI with a computed tomography (CT) scan but who did not ultimately receive a diagnosis of TBI, bringing the total to approximately 5 million TBI-related emergency department visits in the US each year⁴. Moreover, between 2007 and 2013, the rates of TBI-related emergency room visits increased by 47%, a direct result and contributing factor to the growing awareness of symptoms and the effects of concussions.

Current TBI diagnosis in hospital emergency departments relies in large part on CT scans that allow physicians to look at the patient's brain for any signs of bleeding or intracranial brain injury. While a relevant screening tool for severe injuries, the vast majority of mild TBI cases do not show structural brain damage on CT, causing unnecessary radiation exposure in more than 90% of patients receiving a CT scan for TBI⁴. Physicians must then rely on a variety of subjective behavioral and cognitive response tests to diagnose mild TBI cases, often causing wide variability in diagnoses based on a physician's knowledge or discretion. Physicians need a TBI-assessment solution for patients presenting with mild-TBI symptoms that will allow them to make a more objective, quantitative, and rapid diagnosis without requiring patients' unnecessary exposure to radiation.

New Product Attributes and Customer Impact of BrainScope

Headquartered in Bethesda, Maryland, BrainScope is pioneering the future of TBI assessment. The company's innovative *BrainScope One* system (FDA cleared as Ahead 300) leverages state-of-the-art handheld technology and a disposable headset device to empower physicians to make more accurate TBI assessments quickly, at the point-of-care. The *BrainScope One* system's unique design leverages advanced algorithms and machine learning technologies to identify and evaluate key brain electrical activity biomarkers of TBI.

¹ <https://www.cdc.gov/traumaticbraininjury/>

² Taylor CA, Bell JM, Breiding MJ, Xu L. Traumatic Brain Injury–Related Emergency Department Visits, Hospitalizations, and Deaths — United States, 2007 and 2013. *MMWR Surveill Summ* 2017;66(No. SS-9):1–16. DOI: <http://dx.doi.org/10.15585/mmwr.ss6609a1>

³ Centers for Disease Control and Prevention (CDC), National Center for Injury Prevention and Control. Report to Congress on mild traumatic brain injury in the United States: steps to prevent a serious public health problem. Atlanta (GA): Centers for Disease Control and Prevention; 2003.

⁴ Korley FK, Kelen GD, Jones CM, Diaz-Arrastia R. Emergency Department Evaluation of Traumatic Brain Injury in the United States, 2009–2010. *J Head Trauma Rehabil* 2016 Nov/Dec;31(6):379–387.

BrainScope One was engineered to be handheld, easy to use, and to provide a rapid assessment at the point-of-care, to ensure ease of integration in acute assessment without impinging on patient care path. A pioneer in quantitative TBI assessment, BrainScope is poised for rapid and expansive growth. Frost & Sullivan firmly believes that BrainScope is set to become the respected and recognized clinical standard for mild head injury assessment.

BrainScope's Commitment to Providing High-Quality, Objective Data

BrainScope recognized the complex and subjective nature of TBI and set out to develop an assessment tool that provides clinicians with objective data to make a more accurate assessment to aid in determining who is likely to be positive on a CT scan, as well as whether the patient has evidence of abnormal brain function indicative of a concussion. The company focused its system towards answering two primary questions faced by clinicians:

1. Is it likely that a mildly presenting head-injured patient would have structural brain injury visible on a CT scan?
2. Is there evidence of a functional abnormality in the brain that could indicate a concussion?

To effectively address these questions, BrainScope designed the *BrainScope One* system with a combined panel of multi-modal capabilities that allows clinicians to make a more confident assessment, based on objective, physiologically-based information. *BrainScope One* provides a panel of differentiated capabilities, which together provides a comprehensive set of metrics to inform the clinician for them to make their clinical diagnosis and can be configured to meet their needs. The system provides four primary outputs: a CT positive or negative prediction, a Brain Function Index (BFI) score, neurocognitive test results, and digitized assessments.

CT Positive, Negative, or Equivocal Prediction

Focused on aiding in the reduction of the large number of unnecessary CT scans conducted on brain injured patients, BrainScope integrated a rapidly applied, disposable, limited-montage electroencephalogram (EEG) capability (headset) in its system. Quality of the EEG data is ensured by integrating real-time identification and removal of "noise" or artifact in the recorded signal. Characteristics of the EEG signal are then extracted from the clean data, age regressed, and entered into BrainScope's structural injury classification algorithm (the "SIC"), which predicts whether the patient would be positive or negative for brain injury visible on a CT scan. The company also created an additional category—an "equivocal zone"—to alert physicians of patients who were close to the decision border (much like current medical practice used in identifying those who are "pre-hypertensive" or "pre-diabetic") and who may need additional evaluation or observation. Subsequently, the test gives physicians a rapid, objective assessment prior to making the patient undergo a costly CT scan that is potentially unnecessary and would expose them to harmful radiation. In fact,

in its FDA validation trial, sensitivity to the presence of the smallest amount of detectable blood on an independent read of the CT scan ($\geq 1\text{cc}$) was 99%, with negative predictive value (NPV) of 98%.⁵ Furthermore, use of the *BrainScope One* output would have resulted in a 33.3% reduction in the number of false positives (those referred for a CT scan that was found to be negative) compared with clinical site practice.⁶ Extrapolating the 33.3% potential reduction using *BrainScope One* across the incidence rate of mildly presenting TBI patients who receive unnecessary CT scans in emergency rooms, there is the potential for a reduction of over 1 million unnecessary CT scans per year by incorporating *BrainScope One* into standard clinical practice.

Brain Function Index (BFI)

BrainScope created the BFI score to provide physicians additional objective data to inform a clinical assessment of concussion. Using the same rapidly acquired EEG data, *BrainScope One* compares the patient's brain electrical activity to an age-regressed non-head injured population and expresses a score as a percentile relative to that population. The percentile scores are broken into three categories: Average - Patients falling in this category are considered "normal"; Below Average - including those falling one and a half standard deviations away from the mean of normal are considered abnormal; Clearly Below Average - including those falling two standard deviations away from the mean of normal are considered highly abnormal. The score is not meant to provide a binary answer (yes or no) regarding whether the patient is concussed, but to provide a comparison of the patient's functional brain electrical activity to what would be considered "normal". However, as the process relies on signatures specific to concussions, including features that reflect changes in brain region connectivity, it is tailored to a TBI assessment and has the potential to become a highly regarded tool for determining whether or not a patient suffered a concussion. The BFI was validated in the FDA clinical trial and demonstrated to scale with severity of functional impairment, that is, as the BFI percentile goes down, functional impairment increases.⁷ A recently published multiyear study in sports concussion showed the potential clinical utility of the BFI as an EEG based biomarker to assist with more objective evaluation of concussed individuals.⁸

⁵ Hanley D, Prichep LS, Bazarian J, Huff JS, Naunheim R, Garrett J, Jones E, Wright DW, O'Neill J, Badjatia N, Gandhi D, Curley K, Chiacchierini R, O'Neil B, Hack D. Emergency Department Triage of Traumatic Head Injury Using Brain Electrical Activity Biomarkers: A Multisite Prospective Observational Validation Trial. *Academic Emergency Medicine*. 2017; online ahead of print, DOI:10.1111/acem.13175.

⁶ Huff JS, Naunheim R, Ghosh Dastidar S, Bazarian J, Michelson EW. Referrals for CT scans in mild TBI patients can be aided by the use of a brain electrical activity biomarker. *American Journal of Emergency Medicine*. 2017; in press, DOI:10.1016/j.ajem.2017.05.027

⁷ Hanley D, Prichep LS, Badjatia N, Bazarian J, Chiacchierini R, Curley KC, Garrett J, Jones E, Naunheim R, O'Neil B, O'Neill J, Wright D, Huff JS. A brain electrical activity (EEG) biomarker of functional impairment in traumatic head injury: a multisite validation trial. *J Neurotrauma*. 2017. Epub DOI:10.1089/neu.2017.5004.

⁸ Brooks MA, Bazarian JJ, Prichep LS, Ghosh-Dastidar S, Talavage TM, Barr W. The Use of an Electrophysiological Brain Function Index in the Evaluation of Concussed Athletes. *J Head Trauma Rehabil*. 2017. Epub DOI:10.1097/HTR.0000000000000328.

Development of the BrainScope One System

The development of this revolutionary technology represents over a decade of research and product development funded in part by seven Department of Defense contracts, with additional private investment. During this time, BrainScope has addressed several critical issues to foster the adoption of EEG-based technology as an adjunct to acute patient assessment and triage in traumatic brain injury. BrainScope obtained three FDA clearances throughout the development process, culminating in its fourth FDA clearance of the *BrainScope One* device in September 2016.

To date, 22 clinical investigator initiated peer-reviewed publications appeared in the scientific literature based on data collected using the BrainScope devices in development. These publications have demonstrated several important aspects of the BrainScope device, its functionality and potential clinical utility.

Neurocognitive Tests

To further help address the full spectrum of TBI pathology, *BrainScope One* can be configured to incorporate two rapid neurocognitive performance tests to aid the provider in their assessment of the full spectrum of TBI, including concussion. These tests include Complex Reaction Time and visual Match-to-Sample tasks, which are performed right on the *BrainScope One* device. The Complex Reaction Time task measures information processing speed, visuomotor reaction time, simple decision making, and attention. The Match-to-Sample task measures visual-spatial processing, working memory, and visual short-term recognition memory. To aid in interpretability, results of these tests are displayed as a percentile to a non-head injured population within the same age range. For this purpose, BrainScope conducted a large normative study across the age range 18-85 years to establish norms for these tasks when performed on the BrainScope One Device, and demonstrated them to be in registration with previously published normative data.⁹

Further, there are extensive reports in the scientific literature demonstrating the relationship between changes in these neurocognitive performance tasks and the presence of concussive disorders. Importantly, they are complementary to the brain function information reflected in the EEG measures, further contributing to the ability to objectively make the clinical diagnosis of concussion.

Digitized Assessments

BrainScope digitized 17 different neurocognitive test forms which physicians can configure to include during the *BrainScope One* evaluation, supplementing the EEG and

⁹ Vincent AS, Bailey CM, Cowan C, Cox-Fuenzalida E, Dyche J, Gorgens KA, Krawczyk D, Young L. Normative Data for Evaluating Mild Traumatic Brain Injury with a Handheld Neurocognitive Assessment Tool. *Applied Neuropsychology: Adult*. Epub 2016 Aug 11; 1-11.

neurocognitive assessments with the subjective tests and checklists that they may have previously relied on to make an assessment of concussion. These can be administered by the clinician as desired, but are not required as part of the *BrainScope One* assessment.

Multimodal Panel Summary

A multimodal panel summarizes the results of the selected tests – the EEG-based Structural Injury Classifier and Brain Function Index, as well as the neurocognitive tests and digitized assessments if selected - which can be viewed on the device or provided in a summary report, shareable with both patients and providers. The combination of the 2 EEG assessments, the two neurocognitive tests and the digitized assessments as a multimodal platform gives physicians access to new and objective data to help make their clinical diagnosis.

Continued Enhancement of Assessment

BrainScope set out to overcome the complicated, heterogeneous and often subjective nature of TBI assessment. The company integrated its advanced database with information from patients with TBI ranging from non-head injured to functionally impaired to patients with significant structural brain damage from head injury. Its platform was developed using comprehensive patient data, including symptoms, personal history, CT-scan and EEG results, and any neurological tests completed by the clinician both before and after diagnosis. As a result, BrainScope harnessed extensive patient data including CT “clinical truth” after diagnosis which it used in its database to determine particular patterns and create its advanced, machine learning based algorithms validated by BrainScope’s 720-patient FDA clinical trial¹⁰. As the database grows, the system’s machine learning capabilities can be used to identify additional data patterns that can result in algorithms to enhance future assessment capabilities on next generation devices.

***BrainScope One* Design**

BrainScope designed its system to be easy to use, reliable and durable, as it has a range of applications, including emergency room, military and sports settings. The *BrainScope One* includes a disposable headset that attaches to a handheld mobile device, making it easy to use regardless of the setting. The headset has 8 electrodes with labels for easy placement. The electrodes are meant to be placed below the hairline and above the eyebrows, with two ear loops to help guide the placement. Each of the electrodes is comprised of a solid gel, thereby eliminating the need for messy lubricant gels and allowing the headset to be rapidly applied, user-friendly and not requiring any clean-up after testing a patient. The *BrainScope One* includes a handheld device which acts as the processing unit for the system’s signal

¹⁰ Hanley D, Prichep LS, Bazarian J, Huff JS, Naunheim R, Garrett J, Jones E, Wright DW., O'Neill J, Badjatia N, Gandhi D, Curley KC, Chiacchierini R, O'Neil B, Hack D. Emergency Department Triage of Traumatic Head Injury Using Brain Electrical Activity Biomarkers: A Multisite Prospective Observational Validation Trial. *J Acad Emerg Med*. 2017. Epub DOI:10. 1111/acem.13175.

acquisition and algorithms. BrainScope chose to leverage smartphone technology for the system's processing unit as it had the required processing and touch-screen interface capabilities, allowing the company to focus on optimizing the algorithms and software instead of focusing on developing hardware that would replicate smartphones' capabilities.

BrainScope has also developed a very substantial Intellectual Property portfolio of over 100 issued and pending patents, both around TBI as well as other several specific medical indications. BrainScope maintains patents on not only the utility, product and design of *BrainScope One* but also in the areas of advances in EEG systems, electrode placement, multimodality, analysis methods, and care cycle, securing its position to become the leader in TBI assessment.

Mantra of Customer Service

BrainScope identified a range of applications for its system; however, the company understands that the *BrainScope One* system is the first of its kind providing objective data for TBI assessment. Consequently, BrainScope created its Centers of Excellence Program, where it ensures that customers receive full support, from training to marketing support. As the system has numerous capabilities, the company lets customers turn on or off capabilities based on their clinicians' preferences. After the initial upfront process, BrainScope trains the staff members. The company developed the training process which takes about two hours per user thanks to ease of use of the system. Furthermore, physicians only need to order the test and make the assessment using the test results as nursing or clinical staff can conduct the actual test. BrainScope has a 24/7 customer service line which allows customers to ask questions after the initial training process. The company also maintains open communications with customers to gather feedback regarding the system's use and to develop marketing strategies. Additionally, BrainScope sends questionnaires and makes frequent visits to its customers to ensure that it understands how to tailor future innovation and continues to supply enhanced information to physicians for improved patient outcomes. BrainScope also provides users with full marketing packages and works with them to help market their clinics' advanced TBI assessment capabilities in order to acquire more customers. Finally, BrainScope is sponsoring a HIPAA compliant National Registry to study integration of the device in standard clinical use.

High Customer Support and Strategic Expansion

Currently, clinicians can submit for insurance reimbursement for a *BrainScope One* exam under various CPT codes; as the *BrainScope One* is a new system, individual payers will assess certain codes. BrainScope supports customers throughout the reimbursement collection process by providing feedback on best practices on coding and documenting claims pertaining to its device. BrainScope also provides information and documentation to support clinical efficacy of the device which may support claims. The company is partnering with its customers and payers to aggregate data, to highlight the cost-benefits of *BrainScope One*, which includes showcasing the reduced number of unnecessary and costly

CT scans and moving TBI assessment away from the emergency department and towards cost-beneficial clinics, such as urgent care centers. BrainScope recently launched in the US and is experiencing large success in generating interest. The company is leveraging the growing national conversation around concussions and TBI to help expand awareness and bring *BrainScope One* into various markets. The company is focusing currently on bolstering clinical awareness through additional clinical and cost-benefit studies and using key opinion leaders' clout.

Conclusion

Current traumatic brain injury (TBI) assessment and clinical diagnosis relies primarily on subjective testing and costly, radiation-emitting CT scans to determine the extent of an injury. BrainScope created the *BrainScope One* system to provide objective, easy-to-acquire high-quality data to clinicians to assess the full spectrum of TBI severity. The advanced system includes a disposable electrode headset and a reusable, ruggedized handheld device (dedicated smartphone), making it easy to use and highly durable. The company designed *BrainScope One* using state-of-the-art signal processing and machine learning capabilities to create sophisticated algorithms which predict the likelihood that a head injury resulted in a brain injury visible on a CT scan, as well as a Brain Function Index biomarker to help the clinician determine if the patient suffered a concussion. Further, to aid in the assessment of concussion the device can be configured to include two rapid neurocognitive performance tasks, and any of a large battery of digitized assessment tools commonly used in concussion assessment. The device summarizes all assessments performed to give clinicians a full panel with objective data to allow for a more informed clinical diagnosis. Finally, BrainScope commits to supporting its customers by offering them service at every level. From advanced training programs to marketing campaigns to boost their customer's own customer acquisition, the *BrainScope One* system is poised to dominate a growing market for accurate and timely diagnosis of TBI.

With its strong overall performance, BrainScope earns Frost & Sullivan's 2017 North America New Product Innovation Award in the traumatic brain injury assessment solutions market.

Significance of New Product Innovation

Ultimately, growth in any organization depends upon continually introducing new products to the market and successfully commercializing those products. For these dual goals to occur, a company must be best-in-class in three key areas: understanding demand, nurturing the brand, and differentiating from the competition.



Understanding New Product Innovation

Innovation is about finding a productive outlet for creativity—for consistently translating ideas into high-quality products that have a profound impact on the customer.

Key Benchmarking Criteria

For the New Product Innovation Award, Frost & Sullivan analysts independently evaluated two key factors—New Product Attributes and Customer Impact—according to the criteria identified below.

New Product Attributes

- Criterion 1: Match to Needs
- Criterion 2: Reliability
- Criterion 3: Quality
- Criterion 4: Positioning
- Criterion 5: Design

Customer Impact

- Criterion 1: Price/Performance Value
- Criterion 2: Customer Purchase Experience
- Criterion 3: Customer Ownership Experience
- Criterion 4: Customer Service Experience
- Criterion 5: Brand Equity

Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Frost & Sullivan analysts follow a 10-step process to evaluate Award candidates and assess their fit with select best practice criteria. The reputation and integrity of the Awards are based on close adherence to this process.

STEP	OBJECTIVE	KEY ACTIVITIES	OUTPUT
1 Monitor, target, and screen	Identify Award recipient candidates from around the globe	- Conduct in-depth industry research - Identify emerging sectors - Scan multiple geographies	Pipeline of candidates who potentially meet all best-practice criteria
2 Perform 360-degree research	Perform comprehensive, 360-degree research on all candidates in the pipeline	- Interview thought leaders and industry practitioners - Assess candidates' fit with best-practice criteria - Rank all candidates	Matrix positioning of all candidates' performance relative to one another
3 Invite thought leadership in best practices	Perform in-depth examination of all candidates	- Confirm best-practice criteria - Examine eligibility of all candidates - Identify any information gaps	Detailed profiles of all ranked candidates
4 Initiate research director review	Conduct an unbiased evaluation of all candidate profiles	- Brainstorm ranking options - Invite multiple perspectives on candidates' performance - Update candidate profiles	Final prioritization of all eligible candidates and companion best-practice positioning paper
5 Assemble panel of industry experts	Present findings to an expert panel of industry thought leaders	- Share findings - Strengthen cases for candidate eligibility - Prioritize candidates	Refined list of prioritized Award candidates
6 Conduct global industry review	Build consensus on Award candidates' eligibility	- Hold global team meeting to review all candidates - Pressure-test fit with criteria - Confirm inclusion of all eligible candidates	Final list of eligible Award candidates, representing success stories worldwide
7 Perform quality check	Develop official Award consideration materials	- Perform final performance benchmarking activities - Write nominations - Perform quality review	High-quality, accurate, and creative presentation of nominees' successes
8 Reconnect with panel of industry experts	Finalize the selection of the best-practice Award recipient	- Review analysis with panel - Build consensus - Select recipient	Decision on which company performs best against all best-practice criteria
9 Communicate recognition	Inform Award recipient of Award recognition	- Present Award to the CEO - Inspire the organization for continued success - Celebrate the recipient's performance	Announcement of Award and plan for how recipient can use the Award to enhance the brand
10 Take strategic action	Upon licensing, company is able to share Award news with stakeholders and customers	- Coordinate media outreach - Design a marketing plan - Assess Award's role in future strategic planning	Widespread awareness of recipient's Award status among investors, media personnel, and employees

The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of our research process. It offers a 360-degree-view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often companies make important growth decisions based on a narrow understanding of their environment, leading to errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry participants and for identifying those performing at best-in-class levels.

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS



About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best-in-class positions in growth, innovation and leadership. The company's Growth Partnership Service provides the CEO and the CEO's Growth Team with disciplined research and best practice models to drive the generation, evaluation, and implementation of powerful growth strategies. Frost & Sullivan leverages more than 50 years of experience in partnering with Global 1000 companies, emerging businesses, and the investment community from 45 offices on six continents. To join our Growth Partnership, please visit <http://www.frost.com>.