Neurotrauma: A Futuristic Perspective

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The most heterogeneous and complex condition among disorders of the central nervous system (CNS) happens to be traumatic brain injury (TBI). It is poised to become the third most common cause of death and disability worldwide. The failure rate of clinical trials pertaining to TBI is 100%, and till date it lacks specific therapy. The current approach of analyzing small, representative, curated data fails to provide a definite solution. Napoleon Bonaparte once said, "War is 90 percent information." In present-day context, gathering and collating the collected TBI data remains the key to solve mystery of TBI. And no doubt, TBI needs to be attacked on a war footing. The fourth industrial revolution is showing us ways of tackling this most complex disease, of the most complex organ.

Recent buzzwords such as big data analytics (BDA), fuzzy logic (FL), artificial intelligence (AI), brain-computer interface, radiomics, pharmacogenomics and precision medicine, and biologic and immune modulation therapy are increasingly being incorporated into neurosciences. This paper attempts to analyze the current status and future role that these futuristic technologies will play in our conquest against TBI.

An honest attempt has been made to understand the current status of the ongoing technological revolution and predict its impact on management of TBI. It is certain that very soon newer approaches will transform the current practice of triage, diagnosis, treatment, and prognosis of TBI into a highly integrated, evidence-based patient care. In addition, it will also cut down the cost of health care significantly.

Technologies That Hold Promise for Traumatic Brain Injury

Big Data Analytics, Machine Learning, Fuzzy Logic, and Artificial Intelligence

Research on TBI has collected enormous data that can be unstructured, semistructured, or structured. These data have the potential to be mined for valuable information. Analysis of these data powered by machine learning (ML), FL, and AI will revolutionize the field of TBI by the next decade. Current challenge is to collect maximum data from entire world on TBI in a maximal structured format (preferably the electronic health records). Doing so they will guide the health care provider in taking and implementing precise and personalized care of TBI patients.

More data moving more freely into and out of new health IT systems also means more privacy and security concerns. As data diffuse through the ecosystem, the privacy and security risks rise. Moral values and sound ethical guidelines will provide the beacon light for all such endeavors (►**Fig. 1**).

Data Collection Initiatives

The Center TBI and Creative in Europe, Track-TBI and Adapt in the United States, and SP, Polygame, and Neurocare in Canada are projects that have set about collecting high-quality data on TBI. Most of these projects have government funding. The participants in Center TBI will form a knowledge network by way of multicenter, prospective, longitudinal, observational study across 23 countries, which will include data on injury exposure, advanced imaging, genomic, and biomarkers. They will have a follow-up period of 24 months. Results will be integrated with living systematic reviews in a process of knowledge. This high-quality knowledge network aided with novel analytical technologies will help in better characterization of this disease, leading to a new taxonomy of TBI that will transform to precision medicine.

Coupling this big data approach with established preclinical and clinical data will transform current practices for triage, diagnosis, treatment, and prognosis of TBI into highly integrated evidence-based patient care.[1]

Precision Medicine

Precision medicine is an evolving system wherein prevention and treatment are based on identifying an individual's biological signature following analysis of data layers, which includes gene, protein expression, physiologic variables, and environmental and lifestyle factors that endows uniqueness to each individual.[2] This system will help in delivering more effective and targeted therapy for TBI patients.

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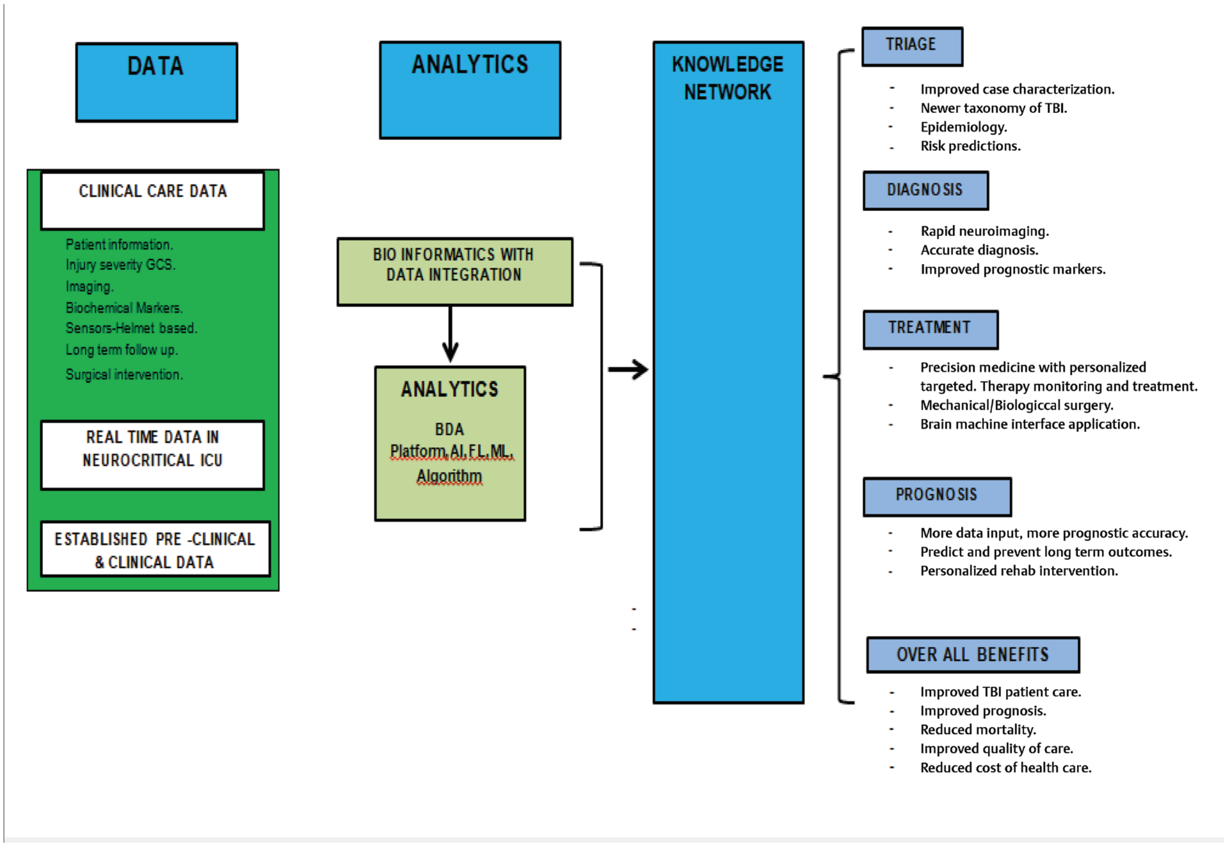

Fig. 1 Representing the traumatic brain injury (TBI) workflow model. AI, artificial intelligence; FL, fuzzy logic; ML, machine learning.

Neurocritical Care

Neurocritical care will be one of the first fields to be transformed by BDA, ML, and AI. Intracranial pressure and blood pressure do not address or tell us about the dynamics of ongoing cellular or neural network dysfunction. Hence, they have proven to be inadequate targets. Newer tools such as cerebral microdialysis and brain tissue oxygen monitoring leave more to be desired. A better insight into the physiologic and anatomical disruption will require incorporation of mechanistic, serum, cerebrospinal fluid, and imaging biomarkers of cellular injury and neural network disruption. Possibly we are not yet measuring the right thing, the right way. In David Menon's words, "We have to make what's important measurable rather than make what's measurable important."[3] The stumbling block in neurocritical care research lies in the fact that we attempt to treat a univariate by focusing on a single intervention or parameter in a multivariate entity, ignoring the complexity of neurocritical condition. BDA and AI/ML will enable us to find correlations between the numerous streaming real-time data from physiologic monitoring, imaging, and biochemical and functional biomarkers. Investigators should reduce the dark data by collecting, storing, and making all these data available to a wide knowledge network for analysis and re-analysis. BDA approaches by companies such as Palantir or Ayasdi have helped in identifying correlations between complex data. These technologies are bound to make the cost of health care cheaper in near future.[1]

One requires a systemic biologic approach that integrates genomics, cellular physiology, metabolomics, proteomics, pharmacogenomics, and the connectome of integrated nervous system networks. This coupled with real-time analytics of the huge continuous streaming data will help improve the taxonomy of TBI patients to assess reactivity index, as surrogate for cerebral autoregulation and help practice precision medicine.[4]

Trauma Surgery

Present era of mechanical surgery (MS) relies more on the neurosurgeon's expertise and the available intraoperative adjunctive technologies. The MS era will shift to an era of biological surgery with deployment of hybrid technologies. This will result in biological manipulation of the CNS. With incorporation of stem cell therapy, regenerative medicine, and immunologic therapy, most disorders of the CNS will come under the realm of biologic therapy. There is bound to be a shift from "sickness responsive therapy" to "preemptive therapy."

Neurotrauma will be the only exclusive field requiring MS. Patient-specific three-dimensional (3D) models are already being used for planning approach and using custom-made implants (especially in craniomaxillofacial and spinal injuries involving the subaxial cervical spine). However, following excision of damaged tissue, subsequent stem cell activation will be used to regrow the damaged or excised portion of the brain and spinal cord (biological therapy).

This regrowth will be guided by CNS maps containing encoded information specific for the individual (e.g., personality), which will be obtained as part of the routine screening surveys.[5] For overcoming functional deficits, non-biologics such as microchip implants and transplantations will be in use. As of now, they are in experimental stage but will soon become a reality.

Imaging in Traumatic Brain Injury

Imaging analytics may be slightly ahead of other domains in terms of AI maturity, but it will still be a slow and difficult process to bring AI into the everyday workflow. Computed tomography (CT) scanning is the only imaging type being used the world over to diagnose TBI. Immediate diagnosis and rapid, automated evaluation improve outcomes in TBI where time is at a premium. AI needs to be told to catalog clinically significant "digital markers" that can be picked up on scans across the board. This will facilitate future precision medicine research by combining data from quantitative image analyses with other types of data. The success of algorithms is proportional to the quantity and quality of data. Algorithms will always be data hungry. It is for the treating surgeon to find the right balance between utility and focus.

Non-biologic Therapy: Engineering Approach

The biological approaches rely on the activation of the endogenous regenerative capacity of the brain and cell transplantation. The engineering approach to brain repair makes use of artificial devices to restore the physiologic brain function by stimulating the CNS (neuromodulation), connecting the brain with an end effector (brain-machine interfaces [BMIs]), or replacing/bypassing the damaged brain tissue (neuroprosthetics).

Neuromodulation

This will find more application in the subacute or later stages of management of TBI. Neuromodulation can be used to stop or modify neural activity or aid in plasticity. These effects can be achieved by electrical or magnetic stimulation (transcranial electrical stimulation [tES] and transcranial magnetic stimulation [TMS]) or by way of electrical pulses being directly delivered into target deep brain areas (deep brain stimulation [DBS]). Responsive neuromodulation has already been approved by the Food and Drug Administration (FDA) as a treatment adjunct for drug-refractory epileptic syndromes.[6]

Intelligent Neuroprostheses—RAMP

European Union-funded project, Real neuronsnanoelectronics Architecture with Memristive Plasticity (RAMP) has given a fillip to neuroplasticity wherein biological neurons can imprint memories in memristors that can go on to mimic natural brain functions.[7,8]

The introduction of memristors could provide a big leap in brain repair as this can do away with the complexity of biological regenerative repair or neural grafts. Jose M. Carmena and group have further enhanced the adaptability of these memristors by incorporating adaptive behavior in a BMI decoder design, in which they define closed-loop decoder adaptation (CLDA).[9]

In the era of exponential progression in medicine and technology, the availability of intelligent bio-hybrid neurotechnologies will offer personalized interventions by inducing a self-repair process in a damaged brain. In short, they will "help the brain to help itself."[10]

Brain-Machine Interface

Trauma to eloquent areas of the brain will find application of BMI to fill the missing void. Brain-computer interfaces (BCIs) backed by AI could restore those lost functions and experiences. By using a BMI and AI, we can decode the neural activates associated with the intended movement of limbs. This can allow the person to communicate and ambulate. BMI can drastically improve quality of life for patients with brain and spinal cord injuries.

Artificial Intelligence-Based Tools

AI-based tools such as voice recognition software and clinical decision support systems help streamline workflow processes in hospitals, lower cost, improve care delivery, and enhance patient experience. Despite its potential to unlock new insights and streamline the way providers and patients interact with healthcare data, AI may pose threats of privacy problems, ethical concerns, and medical errors in its nascent stage. Balancing the risks and rewards of AI in health care will require collaborative effort from technology developers, regulators, end-users, and consumers. Adding AI to integrate to newer technologies is going to change the physician-patient relationship for sure.

Will Artificial Intelligence Replace Neurosurgeons Managing Neurotrauma?

There is a school of thought that prophesizes that robots with AI will make neurosurgeons defunct or extinct in near future. These fears seem to be unfounded. Science is organized knowledge whereas wisdom is organized life. Health care needs a fine balance between knowledge, wisdom, creativity, and empathy. AI cannot replace human empathy. One cannot imagine health care without human empathy. Researchers have also found that physician's sentiment about patients is a dimension to decision making that machines cannot gauge. Arriving at a diagnosis and treating a patient is a nonlinear process. It requires creativity in problem-solving skills and intuition that algorithms and robots can never have. Though AI can analyze huge complex data, its final interpretation will always be within the realm of humans. In the final analysis, it is becoming evident that all the newer technologies are here to help, assist, and empower the neurosurgeon and not to compete in deliverance of health care.

Conclusion

Ultimately it turns out that TBI management is a bid data problem. So far the temptation to form premature theories upon insufficient data has been eluding us from delivering optimal care and achieving good outcomes. The proper integration of big data and powerful analytics holds the key to success for all future endeavors on TBI management. The newer technologies are here to stay and only poised to become more and more powerful. We as humans need to channelize this power to improve and enhance lives of our fellow beings in need.

Conflict of Interest
None to declare.

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