Artificial intelligence as an avenue for research and clinical work related to tic disorders

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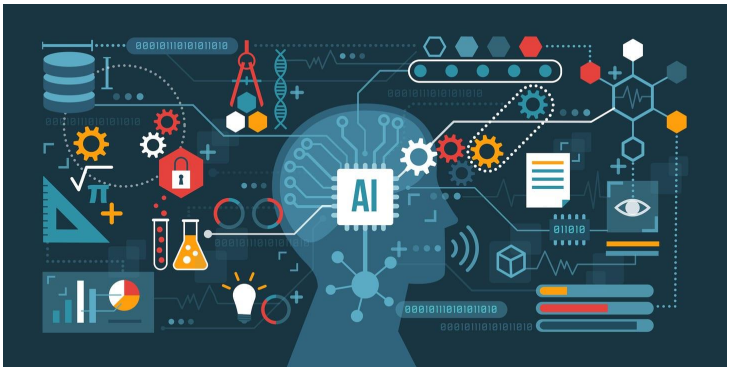
INTRODUCTION

- In recent years there has been a growing number of methodologies aimed to apply new technologies for determination of clinical phenotypes and development of new treatment strategies for patients with tics.
- These include strategies such as **machine learning** and **deep learning** and other modalities of **artificial intelligence (AI)** used to analyze clinical variability of tics, neuroimaging phenotypes or treatment options.



METHODOLOGY

- One reviewer (NS) searched the electronic database of PubMed on April, 2022 for relevant studies using the search terms: ('Tourette syndrome' [MeSH Terms] OR 'Gilles de la Tourette syndrome' [MeSH Terms] OR 'tic disorders' [MeSH Terms] OR 'tics' [MeSH Terms] OR 'tic disorders'[Title/Abstract]) AND ('artificial intelligence' [Title/Abstract] OR 'machine learning' [Title/Abstract] OR 'deep learning' [Title/Abstract], limit: 'humans'.
- These studies were further reviewed for additional relevant citations.
- The titles and abstracts of the studies obtained through this search were examined by the reviewer (NS) in order to determine article inclusion.
- Discrepancies were addressed by the reviewers through discussion and eventually conversation with the senior reviewers (TZ, PN, JP).

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RESULTS

- Our search strategy yield 10 studies which used **AI methodology** in studies dedicated to tics. All in all, these included the topics **of clinical phenotypes**, **neuroimaging** and **response to treatment**.

CLINICAL PHENOTYPES AND RESPONSE TO TREATMENT

- **Paulus et al.** developed a **machine learning** model helpful to differentiate between voluntary movements and tics. They used methodology of **support vector machine (SVM)** to evaluate the impact of each category of **Modified Rush Videotape Rating Scale (MRVRS)**, the motor tic count per minute, age and gender on the classification of individuals into the groups "Tourette syndrome" and "no Tourette syndrome". As a result, they demonstrated that **severity of motor, but not vocal tics, is the best predictor to separate and classify patients with Tourette syndrome (TS) and healthy controls.**
- **Wu et al.** attempted to find an **automatic method** for detecting tic movement to assist in diagnosis and evaluation based on real clinical data and **deep learning** architecture that combines both unsupervised and supervised learning methods. Further evaluation suggested its potential clinical application for auxiliary diagnoses and evaluations of treatment effects.

NEUROIMAGING

- As for neuroimaging studies, previous attempts were mainly focused on application of **machine learning** to analyze neuroimaging phenotypes that can distinguish healthy controls and TS individuals or using these techniques to develop more advanced neurostimulation via **deep brain stimulation (DBS).**
- **Matchen et al.** explored the topic of neural oscillations' control with the application of deep learning. They used a trained artificial neural network capable of accurately estimating the effects of square-wave stimuli on neurons using minimal output information from the neuron. Then they applied the results of this network to solve several related control problems in desynchronization, including desynchronizing pairs of neurons and achieving clustered subpopulations of neurons in the presence of coupling and noise.
- **Wang et al.** proposed classification of tic disorders based on functional MRI with the use of machine learning. They plan to recruit 200 children aged 6-9 years with new-onset tic symptoms and 100 age-matched and sex-matched healthy controls under resting-state MRI scanning. Based on the neuroimaging data of resting-state fMRI, the support vector machine (SVM) model will be built. They plan to construct an SVM model based on functional connectivity for the early diagnosis classification of tic disorders (TD) subtypes.
- Another important avenue are new technologies used for DBS, in particular **inteligent adaptive DBS (closed-loop adaptive DBS).** The goal of this strategy is to identify pathological and physiologically normal patterns of neuronal activity that can be used to adapt stimulation parameters to the concurrent therapeutic demand.

CONCLUSIONS

It can therefore be concluded that all these avenues will serve to plan better, **individualized treatment** for patients with tics. These technologies enable better and personalized planning of treatment, which in the nearest future will be based on the combination of **genetic information, neuroimaging findings and biological biomarkers.**