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REVIEW ARTICLE

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ICS Educational Module: Electromyography in the assessment and therapy of lower urinary tract dysfunction in adults

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Aim: To present the teaching module "Electromyography in the assessment and therapy of lower urinary tract dysfunction in adults." This teaching module embodies a presentation, in combination with this manuscript. This manuscript serves as a scientific background review; the evidence base made available on ICS website to summarize current knowledge and recommendations.

Methods: This review has been prepared by a Working Group of The ICS Urodynamics Committee. The methodology used included comprehensive literature review, consensus formation by the members of the Working Group, and review by members of the ICS Urodynamics Committee core panel.

Results: Electromyography (EMG) is a method to record spontaneous or artificially induced electrical activity of the nerve-muscle unit or to test nerve conductivity. EMG of the anal sphincter using surface electrode is most widely used screening technique to detect detrusor-sphincter dyssynergia in urology. It is non-invasive and easy to perform. EMG methods using needle electrodes are reserved for diagnostics in well selected group of mainly neurogenic patients. These methods require expertise in the field of general EMG and are usually performed by neurologist and neuro-physiologist. The evidence in many aspects of use of EMG in urology remains sparse.

Conclusions: Currently EMG methods rarely play a decision making role in selecting proper treatment of lower urinary tract dysfunction. With the current efforts to improve phenotyping of these patients in order to provide individualized treatment, the role of EMG could increase.

KEYWORDS
bio-feedback, diagnostics, electrode, electromyography, ICS teaching module, urinary incontinence

1 | INTRODUCTION

The role of electromyography (EMG) is to record spontaneous or artificially induced electrical activity of the nerve-muscle unit or to test nerve conductivity. It is a component of the comprehensive urodynamic evaluation, however, the current use of this method is limited. The aim of this communication is to summarize the current evidence regarding the use of EMG in adult urology and provide some suggestions for future research which could lead to further development of this diagnostic and therapeutic method in urology. This paper was prepared by a Working Group of The ICS Urodynamics Committee. The methodology used included comprehensive literature review, consensus formation by the members of the Working Group,

Roman Zachoval led the review process.

and review by members of the ICS Urodynamics Committee core panel. Literature review was performed according to the modified PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) methodology in March 2016.[1] Following Medical Subject Heading (MeSH) were used for electronic search on MEDLINE database: (a) electromyography; (b) neurofeedback; (c) lower urinary tract symptoms; (d) urodynamics; (e) pelvic floor disorders. Terms (a) and (b) were subsequently crossed with (c); (d); and (e). Total 1576 publications were identified. After removing duplications (1576-355 = 1221), all articles published before 1986 (1221-302 = 919) and all articles in other than English language were excluded (919-132 = 787). We identified 81 relevant papers which served as a evidence base for preparation of this manuscript and slide set. The ICS Urodynamics Committee presents this teaching module to serve as a standard education tool for professionals involved in diagnostics and treatment of lower urinary tract dysfunctions. The teaching module consists of a ICS Power Point Presentation, available via http://www.icsoffice.org/eLearning/ and this paper which serves as a scientific background review. The presentation and this manuscript contain experts' opinion where evidence is, especially for the clinical practice aspects, unavailable and is marked with: "eo" (expert opinion).

1.1 | History

EMG is the oldest and most widely used electrophysiological assessment method. The first records of EMG use involved examination of skeletal muscles and it dates back to 19th century. The first sphincter EMG was described by Beck in 1930.[2] The EMG of the anal sphincter was first used in clinical setting by Bailey in 1968.[3] He used EMG as a part of complex neuro-urological evaluation of 184 incontinent children with neurogenic bladder. He also proposed that EMG could be used in adults with neurogenic bladder. Chantrain was the first to conduct comparative studies of skeletal muscle and anal sphincter EMG.[4] In 1979, Mayo included EMG of the anal sphincter into the urodynamic assessment.[5] The future steps in the development of this diagnostic method were marked by neural conductivity studies looking at sacral reflex pathways in 1970s and finally introduction of sensory and motor evoked potentials testing which was first published in 1982.[6,7]

1.2 | Electrophysiology

An intact and functioning motor unit (MU) is the basic component required for adequate function of any muscle. MU consists of a single α-motoneuron residing in the anterior horn of the spinal cord, axon nerve fiber and corresponding muscle fiber. Neurons conduct electrical impulses—action potentials. Action potentials are waves of cell membrane depolarization which travels toward the periphery. The transmission of neural action potential to a respective muscle, which leads to its contraction, takes place at the neuromuscular junction. The action potentials are associated with changes in extracellular and intracellular currents, which could be recorded and processed for their quantitative (frequency and amplitude of action potential) and qualitative (pattern of action potential) characteristics. Simultaneous activation of multiple motor units leads to contraction of a single muscle. Voluntary contraction force is modulated by the number of recruited MU and changes in the activation frequency. The number of recruited MU and their mean discharge frequency of excitation determines the electrical activity, which could be recorded using EMG. There is a direct relationship between the EMG and the muscle force.

1.3 | Technical aspects of EMG

Most clinical EMG devices use a differential amplifier to enhance the display of information. This includes two or more active electrodes placed in proximity to the target muscle or muscle fibers and a common electrode placed equidistant from the active electrodes or on a neutral tissue. The differential amplifier compares the information in all electrodes and discards any information that is the same in all electrodes. This represents the background electrical noise of the body. The remaining information (the target muscle) is then amplified to reduce the influence of artifact or environmental noise on the signal.

Technical parameters of the EMG unit play crucial role in validity of the obtained information. The quality of units used in urology differs significantly. A minimal technical requirement for EMG unit for use in urology should include: Bandwidth: 30 hz-10 kHz; Time scale: 10-100 ms; Sensitivity: 0.1-2.0 mV; 5p DIN connector; 1.5 mm touch-proof connector for common electrode; EMG processing average rectified curve, raw EMG curve, and audio EMG.

1.4 | Electrodes

In general electrodes are used for recording changes in the algebraic sum of motor unit action potentials, or for neural stimulation. The recording unit consists of two or more active electrode and a ground electrode. The size of the electrode determines the specificity of the recording. Larger electrodes are used to record large muscle areas such as the activity of the entire pelvic floor muscle contraction. Smaller electrodes are used to evaluate single motor units. According to their design, technical characteristics and purpose (recording vs stimulation) electrodes are divided in several groups:

Needle electrodes are inserted into the recording muscle and are designed to record single fiber action potentials or action potentials from a small number of units.

1.4.1 | Coaxial needle electrode

Is the most widely used type of needle electrode used in myography performed by neurologists. It consists of the platinum wire (active electrode) which is wrapped in a steel sheet (reference/common electrode). The electrode records the differences in a single action potential between the tip of the platinum wire and the conductive sheet.

1.4.2 | Bipolar needle electrode

Consists of two platinum wires embedded in the sheet and records the difference between action potentials recorded by the two active wires.

1.4.3 | Monopolar needle electrodes

Measure activity recorded by a conically shaped tip of the needle which is embedded in the unconductive sheet. Compared to coaxial needles, it has a larger recording surface, and a wider pick-up field, resulting in higher amplitudes of recorded potentials. This does not allow for recording of action potential from a single muscle fiber and is therefore less specific.

1.4.4 | Surface electrodes

Surface electrodes are placed on the skin overlaying the muscle of interest. This includes both external patch and internal vaginal or rectal probe electrodes. They consist of silver chloride conductive discs or bars. They have a larger reception field, which means that they display a summary of the entire muscle not single action potential. They are however, easy to use and not associated with needle insertion, therefore, despite their low sensitivity they are the most widely used electrodes in urodynamic evaluation.

1.4.5 | Stimulation electrodes

Their principal use is to provoke action potential remotely, which is then picked up by the recording electrode for the purpose of assessing the nerve conductivity and neuro-muscular transmission. They could be designed as both needle or surface electrodes of different shapes according to the type of use (clip electrodes, band electrodes).

2 | EMG METHODS USED IN UROLOGY

2.1 | Needle EMG of anal sphincter

2.1.1 | Principle

External anal sphincter is the component of the pelvic floor which is easiest to identify and target using a needle electrode. Due to close anatomical location and shared innervation, it's activity could implicate the activity of other anatomical structures of the pelvic floor. It is therefore used as a tool for indirect evaluation of the urethral closing mechanism.

2.1.2 | Technique

With the patient in the lateral decubitus or lithotomy position, under digital rectal control, needle electrodes are inserted bilaterally, approximately 0.5 cm lateral to the anus. The depth of insertion is 3-8 cm, depending on patient's constitution.

First, we assess the EMG during maximal relaxation, than during slight pelvic floor muscle contraction or during slow artificial bladder filling. Subsequently we assess the sphincter activity during maximal voluntary contraction of the anal sphincter. To obtain reproducible results it is necessary to record at least 10-20 single action potentials in every phase of the assessment.[8] This assessment is challenging for the patient, time consuming, requiring skills, and expertise.

2.1.3 | Evidence

Anal sphincter EMG using needle electrodes allows the physician to detect disturbances in neuroregulation of the pelvic floor muscles, which could be due to spinal cord injury, lower motor neuron lesion, demyelinating diseases, and Parkinson disease. It could indirectly detect detrusor-sphincter dyssynergia *(eo)*.

However, no systematic study or meta-analysis has been published during last two decades with the topic of the use of needle EMG of the anal sphincter in urology. Currently, only limited evidence based on single center expert opinion is available *(eo)*.

2.2 | Needle EMG of urethral sphincter

2.2.1 | Principle

Direct detection of the activity of the striated external urethral sphincter.

2.2.2 | Technique

In male patients the needles are inserted into the perineum 0.5 cm lateral to the midline at the point of projection of the urethral bulb. The needle tip is directed toward the apex of the prostate and the depth of insertion is controlled by digital rectal examination (DRE) and by acoustic and visual evidence of activity recorded by the EMG equipment. In female patients the electrodes are inserted transvaginal, after the bladder neck is identified with help of a urethral Foley catheter. The recording technique is identical to that of the anal sphincter.

2.2.3 | Evidence

Allows direct recording of the urethral sphincter, however, due to its invasive nature and technical difficulty is used only used in a limited number of carefully selected cases, most often in research studies.[9] Basic work describing the use of needle EMG of the urethral sphincter can be dated back to 1984.[10] More recently Mahajan confirmed the superiority of needle urethral sphincter electrodes compared to surface electrodes.[11] However, only limited evidence based on single center expert opinion is available.

2.3 | EMG of anal sphincter using surface electrodes

2.3.1 | Principle

Non-invasive detection of activity of the entire pelvic floor muscles which is routinely used in urology in course of uroflowmetry or invasive urodynamics.

2.3.2 | Technique

Surface patch electrodes are attached adjacent to the mucocutaneous line of anus bilaterally. The impedance of the skin is reduced using careful degreasing. In some cases a careful epidermis abrasion is required. Excessive hair and adipose tissue around the anal sphincter decrease accuracy of the EMG reading. The electrode wires need to be positioned away from the urine stream. Practitioners are also cautioned not to place the electrodes too lateral in which case the gluteus muscles are being recorded. The common electrode can be placed on the thigh or trochanter. The proper attachment of the electrodes is subsequently tested by recording increased activity during the voluntary pelvic floor contractions.

2.3.3 | Evidence

Evidence for using EMG diagnosis of anal sphincter dysfunction using surface electrodes in adults remains weak. This modality is used for screening purposes to detect detrusor-sphincter dyssynergia in patients with neurogenic bladder and impaired pelvic floor muscle relaxation in patients with dysfunctional voiding. Recently it has been documented that anal sphincter EMG using surface electrodes did not document pelvic floor muscle relaxation during voiding in the majority of a large cohort of patients, suggesting the low sensitivity of this evaluation.[12] However, in pediatric urology literature evidence has been published in support of the beneficial role of simultaneous uroflowmetry and EMG to detect dysfunctional voiding. The argument is that abnormal voiding pattern, that is, staccato and interrupted/fractionated voiding observed on uroflowmetry alone, can lead to overdiagnosis of dysfunctional voiding or detrusor underactivity and that adding simultaneous EMG could significantly improve the diagnostic accuracy.[13] In addition, evidence of usefulness of EMG lag time has been reported in children. EMG lag time is a uroflow/EMG measurement of the time interval between the moment that relaxation of the pelvic floor EMG takes place and the moment urine flow begins. When the lag time is short it is supportive of the diagnosis of detrusor overactivity, while prolongation supports the diagnosis of primary bladder neck dysfunction, especially when they appear in combination with certain LUTS and uroflow patterns.[14] These data should stimulate future studies exploring the role of simultaneous uroflow and EMG in adults.

2.4 | Sacral reflex conductivity testing

2.4.1 | Principle

Stimulation of the pudendal nerve to induce pelvic floor muscle contraction. The presence or absence of response of pelvic floor muscles is evaluated together with recording for latency interval between the stimulus and the response. The goal is to assess the peripheral limb of the micturition reflex.

2.4.2 | Technique

Neurostimulation is performed with surface electrodes attached at the dorsal aspect close to the base of the penis in men and to small labia in women. The response could be recorded by both surface or needle electrodes from the region of anal sphincter or bulbocavernous muscle.

2.4.3 | Evidence

This modality is potentially useful for evaluation of bulbocavernosus and anorectal reflexes.

Absence or delay in response, suggest lower motor neuron impairment. No relevant recent study which could support the role of this examination in daily clinical work-up was found.

2.5 | EMG biofeedback

2.5.1 | Principle

Detect the pelvic floor muscle activity and transform it into a visual and/or acoustic display in order to convey the information to the patient. This is subsequently used for biofeedback training.

2.5.2 | Technique

Surface electrodes are placed close to the anal sphincter (as described above) or inside the vaginal or rectal canal. The recording signal is transformed into sound or visual clue and used to guide the patient to better understand the functional status of the pelvic floor muscles.

2.5.3 | Evidence

This technique is widely used in conservative treatment of incontinence. Acoustic or visual clues help patients to improved awareness of their pelvic floor muscles and to improve their ability to selectively contract the appropriate group of muscles. EMG biofeedback seems to be effective in the conservative treatment of stress urinary incontinence as well as overactive bladder.[15,16] However, there is only limited number of well designed randomized controlled studies to support this observation.

On the other hand, in dysfunctional voiders, EMG biofeedback is used as a tool to help relax the pelvic floor muscles during micturition. While being a well established method in the treatment of voiding dysfunctions in the pediatric population, where combination of acoustic and visual biofeedback plays an important role, evidence in adults is lacking.[17,18](*eo*).

2.6 | Patients perspective

Electromyography does not require any specific patient preparation. Patients must be properly instructedthat insertion of EMG needles is associated with a certain degree of pain. Surface EMG is non-invasive and painless. However, the patient must be informed that hair removal, skin defatting and, in some cases, epidermis abrasion is required before placing electrodes. In all cases, but especially for EMG used for biofeedback, patients should be physicaly and mentaly capable of following instructions given by the health care professional (eg, contraction or relaxation of the pelvic floor muscles).

2.7 | Standards for reporting EMG data

The "Standards for Reporting EMG Data" endorsed by the International Society of Electrophysiology and Kinesiology have been written by Dr. Roberto Merletti.[19] This document summarizes technical information that has to be included for each type of electrode, necessary data on detection mode, amplification, rectification of signal and its computer processing. In addition it provides guidelines on EMG amplitude and frequency processing, normalization, EMG processing for estimation of muscle fiber conduction velocity and EMG crosstalk. Every medical professional using EMG, especially in research, should follow these guidelines.

2.8 | Suggestions for future research

There is a clear lack of evidence in many aspects of the use of EMG in urology. High quality trials are required especially in following topics:

1. EMG pattern of the pelvic floor muscle under physiological and pathological conditions.
2. Role of the EMG in the comprehensive urodynamic evaluation.
3. Role of EMG in the phenotypisation of the patients suffering from LUTS.
4. Role of the pelvic floor muscle EMG as a biofeedback tool in LUT dysfunctions.
5. Role of audio monitoring during EMG in adults.
6. Role of simultaneous uroflowmetry and EMG in detection of voiding dysfunctions, detrusor overactivity, and detrusor underactivity in adults.

3 | CONCLUSIONS

The concept of the use of electrophysiological methods in urology is supported by good theoretical basis. However, the evidence supporting the value of EMG techniques in diagnostics is limited. With the current efforts to improve phenotyping of these patients in order to provide individualized treatment, the role of EMG could increase. In contrary evidence in support of EMG biofeedback exists and should be considered an integral part of conservative treatment of incontinence, OAB, and dysfunctional voiding.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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