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BOTULINUM TOXIN IN THE TREATMENT OF STRABISMUS: A REVIEW OF THE LITERATURE (2015–2025)

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ABSTRACT

Background: Botulinum toxin type A (BoNT-A) has become an important minimally invasive tool in the management of strabismus, either as an alternative or as an adjunct to extraocular muscle surgery. Over the last decade, a growing body of evidence has evaluated its efficacy, safety and optimal indications.
Purpose: To review current evidence (2015–2025) on the use of botulinum toxin type A in the treatment of strabismus, with a focus on mechanism of action, clinical indications, efficacy, safety profile and its role in modern management algorithms.
Methods: Narrative review based on literature published between 2015 and 2025 identified in PubMed, Cochrane Library and major ophthalmology journals. Included were systematic reviews, meta-analyses, randomized controlled trials, observational studies and evidence-based guidelines.
Results: BoNT-A is effective in small- and moderate-angle comitant strabismus, infantile esotropia in selected cases, acquired non-accommodative and acute acquired comitant esotropia, paralytic strabismus and residual postoperative deviations. In some indications its outcomes are comparable to surgery, although repeated injections may be required. Adverse events are usually mild and transient, such as ptosis, transient overcorrection and temporary diplopia.
Conclusions: BoNT-A is an established and safe option in the management of selected forms of strabismus. Further high-quality clinical trials are needed to standardize dosing protocols, timing of intervention and combined approaches with extraocular muscle surgery.

KEYWORDS
Strabismus, Botulinum Toxin, BoNT-A, Extraocular Muscles, Conservative Treatment

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I. Introduction

Strabismus is a disorder of ocular alignment in which the visual axes of the two eyes are not parallel. The consequences of this condition extend beyond purely ophthalmological aspects and include the development of amblyopia, disturbances of binocular vision, reduced quality of life, limitations in professional activity, and psychosocial difficulties. In children, chronic strabismus may lead to the consolidation of abnormal cortical connections, whereas in adults it is frequently associated with distressing diplopia.

Standard management of strabismus includes refractive error correction, amblyopia therapy, and—in selected cases—orthoptic exercises, as well as surgical procedures involving the extraocular muscles. The introduction of botulinum toxin type A (BoNT-A) into clinical practice has provided a minimally invasive therapeutic option based on temporary and reversible weakening of selected extraocular muscles. Over the past decade, numerous clinical studies and systematic reviews have evaluated the efficacy, safety, and optimal indications for BoNT-A treatment in various forms of strabismus.

II. Review Methodology

This review is narrative in nature and was prepared in accordance with the general guidelines of the *International Journal of Innovative Technologies in Social Science* for review articles.

A literature search was conducted using the PubMed/MEDLINE and Cochrane Library databases, as well as selected ophthalmology journals. The following keywords (in English) were used: *strabismus*, *botulinum toxin*, *botulinum toxin A*, *esotropia*, *exotropia*, *infantile esotropia*, *acute acquired comitant esotropia*, *paralytic strabismus*, and *sixth nerve palsy*. Publications from 2015–2025 written in English or Polish were included.

The review incorporated meta-analyses, systematic reviews, randomized controlled trials, prospective and retrospective clinical studies, and current expert guidelines. Selected classic studies published before 2015 were cited solely to provide historical background and to describe the mechanism of action of botulinum toxin.

III. Mechanism of Action of Botulinum Toxin Type A

Botulinum toxin type A (BoNT-A) is a neurotoxin produced by *Clostridium botulinum*. It acts at the neuromuscular junction, where, after binding to receptors on presynaptic cholinergic nerve terminals, it undergoes internalization and induces proteolysis of SNAP-25, a key component of the SNARE complex responsible for the exocytosis of synaptic vesicles containing acetylcholine. This process results in inhibition of neurotransmitter release and reversible muscle paralysis.

In the treatment of strabismus, two main mechanisms of action of BoNT-A are considered relevant:

– a **direct mechanical effect**, consisting of temporary weakening of the overacting extraocular muscle and reduction of the deviation angle;

– a **potential neuroplastic effect**, related to stabilization of a new ocular alignment at the level of the central nervous system, particularly in children with preserved binocular vision potential.

The clinical effect of a single BoNT-A injection typically lasts approximately 3–4 months; however, in some cases, central adaptation and neural reorganization may result in long-term or even permanent correction of ocular alignment.

IV. Clinical Indications for the Use of Botulinum Toxin in Strabismus

Based on current studies and literature reviews, several major groups of clinical indications for the use of botulinum toxin type A (BoNT-A) in the treatment of strabismus can be identified. The most frequently reported clinical presentations, together with typical deviation ranges and primary therapeutic goals, are summarized in **Table 1**.

The main indications include:

– small- and moderate-angle concomitant strabismus, both esotropic and exotropic;

– infantile esotropia;

– acquired esotropia, including acute acquired comitant esotropia (AACE) and acquired non-accommodative esotropia (ANAET);

– paralytic strabismus, particularly due to sixth cranial nerve palsy, less commonly involving the third or fourth nerve;

– residual or recurrent strabismus following extraocular muscle surgery;

– specific clinical situations, such as strabismus associated with neurological disorders, high myopia, or previous orbital surgery.

In many of these indications, BoNT-A may serve as an alternative to surgical treatment or as an adjunctive therapy, allowing reduction of the deviation angle, alleviation of diplopia, and limitation of the extent of surgical intervention.

Table 1. Main groups of indications for the treatment of strabismus with botulinum toxin type A

Indication group	Representative clinical situations	Typical angle of deviation (PD)	Main therapeutic goal
Small- and moderate-angle concomitant strabismus	Acquired esotropia; small-angle exotropia with preserved fusion potential	10–30	Angle correction, improvement of binocular fusion
Infantile esotropia	Large-angle esotropia in infants and young children	≥30–40	Reduction of deviation, improvement of conditions for binocular vision
Acquired esotropia (AACE, ANAET)	Sudden-onset comitant esotropia in children and young adults	15–35	Rapid reduction of diplopia and angle of deviation
Paralytic strabismus	Sixth nerve palsy; less frequently third or fourth nerve palsy	Variable, often large	Reduction of diplopia, improvement of ocular motility
Residual / recurrent strabismus	Small residual deviation after extraocular muscle surgery	<20–25	Avoidance of reoperation
Special clinical situations	Strabismus associated with neurological disorders, high myopia, or following orbital surgery	Variable	Individualization of treatment

V. Injection Technique and Dosage

The most commonly used botulinum toxin preparations in strabismus treatment are onabotulinumtoxinA, abobotulinumtoxinA, and incobotulinumtoxinA. The activity units of these preparations are not interchangeable, which necessitates cautious interpretation of dosing data and precludes direct dose comparisons.

In pediatric patients, typical doses range from 2.5 to 5 units of onabotulinumtoxinA per muscle, whereas in adults doses of 2.5–10 units are commonly used, depending on the deviation angle, the muscle involved, and the intended therapeutic goal. Increasing the dose may result in a stronger clinical effect but is associated with a higher risk of adverse effects, such as transient upper eyelid ptosis or overcorrection.

Injections are most commonly performed via a transconjunctival approach directly into the belly of the extraocular muscle. Muscle localization may rely on anatomical landmarks, electromyographic (EMG) guidance, or—in specialized centers—high-resolution ultrasonography. For medial rectus injections, the needle is typically introduced a few millimeters from the limbus in the medial conjunctival quadrant and advanced parallel to the globe wall.

VI. Efficacy of Botulinum Toxin in Different Types of Strabismus

The efficacy of botulinum toxin type A (BoNT-A) in the treatment of strabismus has been evaluated in numerous clinical studies published over the past decade. The most relevant data regarding treatment effectiveness across different types of strabismus, along with factors associated with favorable outcomes, are summarized in **Table 2**.

Infantile esotropia. Prospective and retrospective studies indicate that BoNT-A injections into the medial rectus muscles can lead to significant reduction of the deviation angle and, in some patients, achievement of stable microtropia. Treatment efficacy is higher in children treated at an early age, with moderate baseline angles and preserved binocular vision potential.

Acquired esotropia (AACE, ANAET). High effectiveness of BoNT-A has been demonstrated both as first-line therapy and as an alternative to surgical intervention. A short interval between symptom onset and toxin injection appears to be a key determinant of long-term success.

Intermittent exotropia. BoNT-A may effectively reduce the deviation angle and improve control of ocular alignment; however, most studies report superior improvement in stereopsis following surgical treatment. Consequently, botulinum toxin is generally considered in patients with contraindications to surgery or as a temporary therapeutic option.

Paralytic strabismus. In patients with sixth nerve palsy, BoNT-A injection into the medial rectus muscle reduces diplopia and improves abduction. This approach may serve as bridging therapy prior to surgery or as definitive treatment in patients with high surgical risk.

Residual or recurrent strabismus. In patients with small residual deviations following surgery, BoNT-A may help avoid reoperation by providing additional angle reduction with minimal patient burden.

Table 2. Summary of the effectiveness of BoNT-A in selected types of strabismus

Type of strabismus	Approximate success rate	Factors associated with better outcomes	Comments
Infantile esotropia	40–60% achievement of stable microtropia	Early treatment, moderate baseline angle, preserved fusion potential	Further surgery often required in large-angle deviations
AACE / ANAET	60–80% restoration of satisfactory ocular alignment	Short duration of symptoms, absence of severe sensory deficits	Possible alternative to surgical treatment
Intermittent exotropia	Significant reduction of the deviation angle in most patients	Good control of deviation, mild or intermittent course	Surgery more effective in improving stereopsis
Paralytic strabismus (VI nerve palsy)	Marked reduction of diplopia in the majority of patients	Early initiation of treatment, partial potential for spontaneous recovery	Bridging and symptomatic treatment
Residual strabismus after surgery	High rate of reduction of small residual deviations	Small residual angle, absence of significant sensory disturbances	Alternative to reoperation

VII. Comparison of Botulinum Toxin and Conventional Extraocular Muscle Surgery

In recent years, multiple studies have compared botulinum toxin type A (BoNT-A) injections with conventional extraocular muscle surgery in selected forms of strabismus. The key differences between these therapeutic approaches, including their advantages and preferred treatment strategies, are summarized in **Table 3**.

In acute acquired esotropia in children and young adults, BoNT-A has been shown in several analyses to be non-inferior to surgery in terms of deviation angle correction and improvement of sensorimotor function during 1–3 years of follow-up. Its advantages include shorter anesthesia time, lower invasiveness, and the possibility of repeated treatments.

In contrast, surgery remains the gold standard for intermittent exotropia, providing a greater likelihood of full stereopsis restoration. Nevertheless, BoNT-A may be considered in patients with contraindications to surgical treatment or as part of a staged therapeutic approach.

Meta-analyses and systematic reviews emphasize that although BoNT-A is less invasive, the quality of evidence directly comparing this method with surgery remains limited. Therefore, treatment decisions should be individualized, taking into account patient age, strabismus type and angle, presence of sensorimotor disturbances, and expectations regarding treatment durability.

Table 3. Comparison of botulinum toxin type A and surgery in selected indications

Indication	Advantages of BoNT-A	Advantages of surgery	Most commonly preferred strategy
AACE in children	Lower invasiveness, shorter anesthesia time, possibility of repeated treatments	Single procedure with stable long-term effect	BoNT-A or surgery – individualized decision
Intermittent exotropia	Option for patients with contraindications to surgery	Better improvement of stereopsis, predictable outcome	Surgery as standard treatment, BoNT-A as an alternative
Residual strabismus after surgery	Avoidance of reoperation, minimal patient burden	Possibility of complete correction in larger angles	BoNT-A preferred for small residual deviations
Paralytic strabismus	Rapid reduction of diplopia, bridging treatment	Surgery only after stabilization of the paresis	BoNT-A as first-line treatment

VIII. Safety and Adverse Effects

The safety profile of botulinum toxin type A (BoNT-A) in the treatment of strabismus is considered favorable. The most commonly reported adverse effects include:

– transient upper eyelid ptosis;
– transient overcorrection (change in deviation direction);
– transient diplopia;
– minor subconjunctival hemorrhage at the injection site.

Most of these effects are mild and resolve spontaneously within several weeks without the need for specific treatment. Serious complications, such as globe perforation, intraocular infection, or permanent damage to the extraocular muscle, are exceedingly rare and are typically associated with improper injection technique or inappropriate patient selection.

Minimizing the risk of adverse effects requires adequate operator experience, careful dose selection, and precise injection technique with consideration of orbital anatomy and adjacent structures.

IX. Discussion and Future Perspectives

The use of botulinum toxin type A (BoNT-A) in the treatment of strabismus reflects the broader development of modern minimally invasive medical technologies. Although BoNT-A does not fully replace extraocular muscle surgery, it represents an important therapeutic tool, particularly in selected patient populations and specific clinical indications.

From a social sciences perspective, BoNT-A treatment may be associated with shorter recovery times, fewer days of work incapacity, reduced caregiver burden, and greater patient acceptance among individuals reluctant to undergo surgical procedures. These aspects are relevant for the analysis of indirect costs and cost-effectiveness of strabismus management at the healthcare system level.

At the same time, literature published over the past decade highlights substantial heterogeneity in dosing protocols, injection techniques, and outcome measures, which complicates direct comparison of study results and limits the formulation of unequivocal clinical recommendations. Further well-designed randomized controlled trials with long-term follow-up are needed to standardize treatment approaches and to more precisely define optimal indications for BoNT-A use in strabismus.

X. Conclusions

Botulinum toxin type A (BoNT-A) represents an effective and safe treatment option for selected forms of strabismus in both pediatric and adult patients.

The greatest clinical benefits are observed in cases of small- to moderate-angle deviations, acquired esotropia, paralytic strabismus, and small residual deviations following surgical treatment.

In selected clinical indications, BoNT-A may serve as an alternative to conventional extraocular muscle surgery, particularly in patients with contraindications to operative treatment or significant concerns regarding surgery.

The safety profile of BoNT-A therapy is favorable, with most reported adverse effects being mild and transient.

Future research should focus on standardizing dosing regimens, defining optimal timing of therapeutic intervention, and evaluating the impact of treatment on patient quality of life and indirect costs.

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