East and North Hertfordshire Teaching NHS Trust

Ergonomic Evaluation of Exoskeleton Use in Transoral, Endoscopic, and Transcervical ENT surgery: A single site non-blinded study

Short Title: Exoskeleton ENT

Protocol Reference/RD no: RD2026-23
Version number: v 2.0
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Study Chief Investigator: Mr A Vijendren
Study Sponsor: East & North Hertfordshire NHS Trust, Lister Hospital, Coreys Mill Lane, Stevenage, SG1 4AB
IRAS ID: 369967

This protocol has regard for the HRA guidance

CONFIDENTIAL

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Ergonomic Evaluation of Exoskeleton Use in Transoral, Endoscopic, and Robotic Head and Neck Surgery
Exoskeleton ear

Study Sponsor	East & North Hertfordshire NHS Trust Lister Hospital, Coreys Mill Lane, Stevenage, Hertfordshire, SG1 4AB United Kingdom Telephone:
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Protocol Signature Page
Ergonomic Evaluation of Exoskeleton Use in Transoral, Endoscopic, and Transcervical ENT surgery

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Approved by Chief Investigator:



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Ananth Vijendren, BM MRCS MRCS (ENT) FRCS (ORL-HNS) PhD

Date: 24.05.2026

Investigator's Agreement

The undersigned confirm that the final protocol has been reviewed, agreed upon, and accepted. The Chief Investigator affirms their commitment to conduct the study in full compliance with the approved protocol, the principles of the Declaration of Helsinki, the Sponsor's standard operating procedures, and all applicable regulatory requirements.

The Chief Investigator further agrees that all confidential information contained within this document will be used solely for the evaluation or conduct of the clinical investigation, and will not be disclosed or applied for any other purpose without prior written authorisation from the Sponsor, East & North Hertfordshire NHS Trust.

In addition, the Chief Investigator confirms their responsibility to ensure that the study findings are made publicly available—through publication or appropriate dissemination—without undue delay, and that the study will be reported honestly, accurately, and transparently. Any deviations from the approved protocol will be clearly described and justified in the final account.



Ananth Vijendren, BM MRCS MRCS (ENT) FRCS (ORL-HNS) PhD 24.05.2026

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Trial Administration

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Protocol Synopsis

Study Title	Ergonomic Evaluation of Exoskeleton Use in Transoral, Endoscopic, and Transcervical ENT surgery: A single site non-blinded study
Short Title	Exoskeleton ENT
Type of Trial	Single-site non-blinded cross-over prospective cohort study
Study Period	12 months
Objectives	1. To investigate the effects of the exoskeleton system on musculoskeletal strain during live transoral, endoscopic, and transcervical ENT operations. 2. To compare subjective pain scores and object surface EMG and MVC data in neck, shoulder and wrist muscles in transoral, endoscopic, and transcervical ENT operations with and without the exoskeleton
Outcome measures	Objective outcome measure 1. sEMG data from neck and shoulder muscles 2. MVC data from neck, shoulder and wrist muscles before and after the surgical procedure. Subjective outcome measure

	1. Visual analogue scale scores at 10-minute intervals
Study Design and Methodology	Comparison between objective and subjective outcome measure during transoral, endoscopic, and transcervical ENT operations with and without the exoskeleton
Indication	-
Planned Trial sites	Single site
No of Participants	30 participants (30 operations with the exoskeleton and 30 operations without the exoskeleton for each arm of the study.)
Eligibility Criteria	• ENT surgeons who perform a range of transoral, endoscopic, and transcervical ENT operations. • Willing to participate with surface EMG (sEMG) monitoring and utilise the Ottobock exoskeleton
Treatment	N/A
Assessment Schedule	N/A
Statistical Methodology and analysis	JASP to assess data conformity. Wilcoxon signed rank test for likely non-parametric data comparisons.

Study Glossary

Commonly used abbreviations [**add/delete as applicable, NB – this is <u>not</u> an exhaustive list]**

AE	Adverse Event
CI	Chief Investigator
CRF	Case Report Form
CRO	Contract Research Organisation
DMC	Data Monitoring Committee
GAfREC	Governance Arrangements for NHS Research Ethics
GCP	Good Clinical Practice
GP	General Practitioner
HRA	Health Research Authority
ICF	Informed Consent Form
ISF	Investigator Site File
ISRCTN	International Standard Randomised Controlled Trials Number
Main REC	Main Research Ethics Committee
NHS R&D	National Health Service Research & Development
NIHR	National Institute for Health Research
NIMP	Non-Investigational Medicinal Product
PI	Principal Investigator
PIS	Participant Information Sheet
QA	Quality Assurance
QC	Quality Control
RCT	Randomised Control Trial
REC	Research Ethics Committee
SAE	Serious Adverse Event
SDV	Source Document Verification
SOP	Standard Operating Procedure
SSA	Site Specific Assessment
TMG	Trial Management Group
TSC	Trial Steering Committee
WHO	World Health Organisation
sEMG	Surface Electromyography
SENIAM	Surface electromyography for non-invasive assessment of muscles
VAS	Visual analogue scale

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1 INTRODUCTION

1.1 Background

Work-related musculoskeletal disorders (WRMD) represent a substantial occupational challenge for otolaryngologists, who frequently operate in constrained positions that place considerable strain on the neck, back, and upper limbs. Surveys of ENT surgeons consistently demonstrate a high prevalence of MSK pain: Babar-Craig and colleagues reported widespread neck and back discomfort among UK consultants, while Vijendren et al. later showed that MSK symptoms are far more common than generally acknowledged, suggesting that published figures likely underestimate the true extent of the problem (1,2,3). Further work by Vijendren and co-authors demonstrated that prolonged microscopic activity—a routine component of ENT practice—significantly increases cervical and lumbar strain, although ergonomic aids such as specialised postural support chairs may help reduce this burden (4). These findings collectively highlight the persistent ergonomic challenges faced by ENT surgeons, particularly as transoral, endoscopic, and transcervical approaches become more prevalent and impose additional static and asymmetric postures. Given the high incidence of WRMD and the limited ergonomic training available within the specialty, there is a clear need to explore novel strategies—such as upper-body exoskeletons—to help mitigate physical strain during minimally invasive head and neck procedures and support long-term surgeon well-being.

1.2 Preclinical/Clinical Data

Exoskeletal systems have been developed to reduce musculoskeletal strain by supporting the upper body during prolonged or repetitive tasks. Industrial studies demonstrate that lightweight passive exoskeletons can decrease muscle activation and perceived effort while maintaining full mobility (5,6),

and devices such as those from Ottobock are designed for workplace postural support (7). Early clinical evidence suggests benefits for surgeons, including reduced neck, back, and shoulder discomfort in orthopaedic procedures (8) and improved ergonomics during endoscopic sinus and skull-base surgery (9). However, no studies have evaluated exoskeleton use across broader ENT procedures, including transoral, endoscopic, microscopic or transcervical head and neck surgery. Given the high prevalence of work-related musculoskeletal disorders among ENT surgeons, exoskeletons represent a promising intervention to reduce ergonomic strain and support long-term surgeon health.

1.3 Rationale

We feel that the exoskeleton system can help reduce the physical strain experienced by surgeons while performing any form of ENT operations. We have divided the breadth of ENT operations into microscopic, endoscopic, transoral and transcervical operations. We already have another project due to start looking at exoskeleton use amongst microscopic procedures.

2 STUDY OBJECTIVES AND DESIGN

2.1 Objectives

2.1.1 Primary objective:

1. To investigate the effects of the exoskeleton system on musculoskeletal strain during live transoral, endoscopic and transcervical ENT operations.
2. To compare subjective pain scores and object surface EMG (Electromyography) and MVC (Maximal Voluntary Contraction) data in neck, shoulder and wrist muscles in transoral, endoscopic and transcervical ENT with and without the exoskeleton.

2.1.2 Secondary objectives:

1. To investigate the timing and duration taken to put on the exoskeleton during live surgery.
2. To determine if the exoskeleton has any effect and bearing on operating capacity of the surgeon.

2.2 Endpoints/outcomes

2.2.1 Primary Endpoints/outcomes:

The study will continue until the end of the operation.

2.2.2 Secondary Endpoints/outcomes:

None.

2.3 Study Design

This study will be conducted as a prospective observational investigation. A collaboration has been established between the ENT Department at East and North Herts NHS Trust and the Institute of Sport Sciences at the University of Hertfordshire. Participant recruitment and data collection will take place at the Lister Hospital, Stevenage. The University of Hertfordshire will provide the EMG and MVC equipment and expert support for data analysis. The Ottobock Exoskeleton system (7) will be acquired using funding from the Research Capacity Funding scheme.

2.3.1 Number of subjects

20 operations in each category of transoral, transcervical and endoscopic totaling 60 operations.

2.3.2 Study Duration

1 year.

2.3.3 End of Study

The sponsor will inform the REC within 90 days of the ‘end of trial’ that the study has closed.

Following the submission of end of trial notification to the REC, the sponsor should ensure that end of trial report is submitted within 12 months of this notification. In circumstances of early termination of the trial or temporary halt by the sponsor, the sponsor will notify the REC within 15 days of the decision and a detailed, written explanation for the termination/halt will be given.

3 SUBJECT SELECTION AND RECRUITMENT

3.1 Inclusion Criteria

- ENT surgeons who perform a range of transoral, endoscopic and/or transcervical ENT operations.
- Willing to participate with surface EMG (sEMG) monitoring and utilise the Ottobock exoskeleton.
- • Prior familiarisation with the Ottobock exoskeleton, evidenced by completion of at least five (5) documented surgical procedures using the device before enrolment in the study.

3.2 Exclusion Criteria

- Pre-existing musculoskeletal problems that limits transoral, endoscopic and/or transcervical ENT operations
- Inability to safely or effectively perform surgery using the Ottobock exoskeleton.
- Lack of prior familiarisation with the Ottobock exoskeleton, defined as failure to complete at least five (5) documented surgical procedures using the device prior to enrolment in the study.

3.3 Subject Recruitment and Screening

Clinicians within the ENT Department will be invited to participate voluntarily through posters and email communications distributed via the Trust. Interested participants will be screened by the PI to confirm eligibility, ensuring that all inclusion criteria are met and no exclusion criteria apply.

4 SUBJECT WITHDRAWAL

- Participants can withdraw for any reason. This would include:
  - Unduly musculoskeletal strain during surgery
  - Unable to operate using the exoskeleton
  - Clinical / intraoperative complications

5 STUDY PROCEDURES AND SCHEDULE OF ASSESSMENTS

5.1 Informed consent

Participants will receive detailed information about the study and all associated procedures. They will be given a minimum of 24 hours to consider this information and to ask any questions before providing written informed consent (see Appendix C). Although any member of the research team may conduct the initial briefing, it is the responsibility of the PI, or a delegated designee, to obtain written informed consent from each participant before any study procedures begin. The PI must ensure that participants receive a clear explanation of the study's aims, methods, anticipated benefits, and potential risks. The PI will also document the date on which the Participant Information Sheet (PIS) (Appendix B) is provided. If consent is obtained in less than 24 hours, the PI must provide a justification for the shortened timeframe.

Participants will be informed that participation is voluntary, that they may withdraw at any time without giving a reason, and that consent does not automatically constitute enrolment in the study. A copy of the signed informed consent form will be given to the participant, and the original will be securely stored at the study site. If new safety information emerges that materially alters the risk–

benefit profile, the consent form will be updated and participants will be re-consented as appropriate. For participants who cannot read or write, require translation, or have cognitive impairment, suitable alternative consent methods will be employed. These may include the presence of an independent witness, signature or dating of the form by a representative, or provision of the PIS in an accessible format or alternative language. If a participant initially provides valid consent but subsequently loses capacity, the original consent will remain valid provided that the study procedures have not undergone substantial change. Clinical judgement may, however, necessitate discontinuation of study interventions, while follow-up data collection may continue where appropriate.

5.2 Trial Procedures by Visit

Please see schedule of assessment below:

Procedure	Study period	
	Screening	[Visit 1]
Informed consent	X	
Eligibility criteria	X	
Baseline information		X
Data recordings		X

5.3 Screening and Baseline assessments

Data will be collected on the following:

- Transoral/ Endoscopic/ Transcervical ENT surgery experience (months)
- Previous musculoskeletal injuries
- Any existing musculoskeletal strain / pain

5.4 Study assessments and procedures

After informed consent is obtained, participating ENT surgeons will be fitted with the Ottobock exoskeleton in accordance with manufacturer guidance (7). Surgeons will prepare for their procedures following standard operating protocols. Before scrubbing, the skin of the neck and shoulder muscles area will be cleaned with alcohol gel and allowed to dry, and surface EMG electrodes will be applied to the neck and shoulder muscles following SENIAM recommendations (10,11). The surgeon will then either be seated in a standard operating chair or stand in the appropriate position, and asked to adjust the chair height, operating table height, and body posture to minimize baseline strain. The sEMG recordings will start at the beginning of surgery and a member of the study team will take the subjective measurements every 10 minutes. Additionally, before and after the surgical procedure, and after EMG placement, we will collect 3 neck and shoulder MVC trials from dominant and non-dominant hand. Wrist fatigue will be assessed using MVC measurements only. Again, three wrist MVC trials will be collected before and after the surgical procedure for both the dominant and non-dominant hands. EMG electrode placement will not be performed, as it would interfere with the required surgical scrubbing and antiseptic requirements. Data collection will conclude at the end of the procedure. Measurements will be conducted using a standardized protocol across 30 transoral, 30 endoscopic, and 30 transcervical cases performed with the exoskeleton in place. The protocol will then be repeated for an additional 30 cases in each category without the exoskeleton. In total, 60 major cases per category will be recorded, resulting in 180 patient cases overall. These numbers were selected from a previous paper using exoskeleton in simulated ENT procedures where the total number of participants were 13. (9) There are no patient exclusion criteria. Although this is an observational study involving surgeons, patients will be informed that their surgeon may use an exoskeleton device during their procedure. A

brief information sheet will be provided in advance (Appendix A), explaining that the device is worn by the surgeon, does not directly affect the patient, and does not alter standard care.

Patients will have the opportunity to ask questions and may decline the use of the device without any impact on their treatment. As no additional patient data are collected and there is no direct intervention, formal written consent will not be sought; however, patient awareness and preferences will be respected and incorporated into routine clinical discussions.

5.5 End of study procedures

The study ends at the end of each individual surgery.

Data collection and entry.

1. Subjective measurements

A data collection proforma (Appendix D) will be completed for each participant and assigned a randomly generated unique study identifier prefixed with "T" for transoral surgery (e.g. T1, T2, T3), "E" for endoscopic surgery (e.g. E1, E2, E3) and "TC" for transcervical surgery (e.g. TC1, TC2, TC3). The proforma will record ENT experience, any pre-existing musculoskeletal conditions, baseline strain or pain, and visual analogue scale measurements collected during the recordings. The linkage between the unique study identifier and participant identifiable information (name, date of birth, and address) will be stored in a pseudo-anonymised, password-protected Excel file on the Trust ENT shared drive, accessible only to the research team. Hard copies of consent forms and original data sheets will be stored securely within the Research Team office in accordance with GDPR and Trust data governance policies. No identifiable information will appear on any data collection forms used for analysis.

2. Objective measurements

Recordings obtained from the sEMG will be saved to an encrypted USB drive, labelled only with each participant's unique study identifier. No identifiable patient information will be stored or transferred. The anonymised sEMG and MVC files will be sent to the University of Hertfordshire research team for analysis via encrypted email (e.g., NHSmail or EGRESS). All analysed data will be stored in Excel files or using Trialflare platform, reported as percentage change in amplitude from resting sEMG and maximum sEMG values.

Primary Outcome Measures:

- Differences in VAS and motor unit firing (via sEMG) of participants with and without the exoskeleton during transoral, endoscopic and transcervical ENT surgery.
- Change in motor unit firing during MVC comparing before and after the surgical procedure.

Secondary Outcome Measures:

- Differences in baselines characteristics of participants
- Differences in time of set up for exoskeleton

6 SAFETY REPORTING

6.1 Definitions

6.1.1 Adverse Event (AE)

An adverse event (AE) is defined as any symptom, sign, illness, or experience that develops or worsens in severity during the course of the study. Intercurrent illnesses or injuries are also

considered adverse events. Abnormal findings from diagnostic procedures should be classified as adverse events if the abnormality:

- results in withdrawal from the study;
- is associated with a serious adverse event;
- is accompanied by clinical signs or symptoms;
- necessitates additional treatment or further diagnostic investigations; or
- is deemed clinically significant by the Investigator.

6.1.2 Serious Adverse Event (SAE)

A serious adverse event is any AE that is:

- Fatal
- life-threatening
- requires or prolongs hospital stay
- results in persistent or significant disability or incapacity
- a congenital anomaly or birth defect
- an important medical event.

6.1.3 Disease related Events/outcomes NOT qualifying as SAEs

An event that is part of the natural course of the disease under study, such as disease progression, should not be reported as a SAE. However, if the progression of the underlying disease exceeds what would normally be expected for the participant, or if the investigator determines that there is a causal

relationship between the study intervention or protocol procedures and the disease progression, the event must be reported as an SAE.

Important medical events are those that may not be immediately life-threatening but are of major clinical significance. Such events may place the participant at risk and may require intervention to prevent one of the other serious outcomes described above.

6.1.4 Pre-existing conditions

A pre-existing condition is defined as any condition present at the start of the study. A pre-existing condition should be recorded as an AE if its frequency, intensity, or characteristics worsen during the study period.

At screening, any clinically significant abnormality should be documented as a pre-existing condition. At the end of the study, any new clinically significant findings or abnormalities that meet the definition of an AE must also be recorded and documented as an adverse event.

6.2 Investigator Assessments

6.2.1 Seriousness

When an AE/AR occurs, the investigator responsible for the participant's care must first assess whether the event meets the criteria for seriousness, using the definitions provided above. If the event is determined to be serious and is not exempt from expedited reporting, an SAE form must be completed.

6.2.2 Causality

The Investigator must assess the causality of all adverse events in relation to the trial therapy using the definitions provided. There are five causality categories: unrelated, unlikely, possible, probable, and definitely related. For reporting purposes, events assessed as unrelated or unlikely to be related will

not be considered adverse reactions to the trial therapy. Events assessed as possible, probable, or definitely related will be classified as adverse reactions for reporting purposes.

Table 3. Definitions of Causality

Relationship	Description
Unrelated	There is no evidence of any causal relationship.
Unlikely	There is little evidence to suggest there is a causal relationship (e.g. the event did not occur within a reasonable time after administration of the trial intervention). There is another reasonable explanation for the event (e.g. the patient's clinical condition, other concomitant treatment).
Possible	There is some evidence to suggest a causal relationship (e.g. because the event occurs within a reasonable time after administration of the trial intervention). However, the influence of other factors may have contributed to the event (e.g. the patient's clinical condition, other concomitant treatments).
Probable	There is evidence to suggest a causal relationship and the influence of other factors is unlikely.
Definitely	There is clear evidence to suggest a causal relationship.

6.2.3 Expectedness

Expected SAEs associated with the disease and the trial intervention should be listed in the protocol. Investigators must maintain the current version of the Expected Adverse Events list in the safety reporting section of their Investigator File.

6.2.4 Grading

Common Terminology Criteria for Adverse Events (CTCAE) a standardized classification and grading system, will be used to describe the severity of adverse events.

Most adverse events are graded on a 5-point scale:

Grade	Meaning
Grade 1	Mild; asymptomatic or mild symptoms
Grade 2	Moderate; minimal intervention indicated
Grade 3	Severe or medically significant
Grade 4	Life-threatening consequences
Grade 5	Death related to the adverse event

6.3 Reporting of AEs and SAEs

At each contact with a participant, the investigator must actively seek information on adverse events through specific questioning and, as appropriate, through examination. All adverse events should be recorded immediately in the source documents and in the appropriate adverse event module of the case report form (CRF). All clearly related signs, symptoms, and abnormal diagnostic test results should be recorded in the source document, though they should be grouped under a single diagnosis. Methods to detect adverse events may include one or more of the following:

- Information volunteered by the participant or caregiver
- Open-ended and non-leading verbal questioning at each visit (for example, “How are you feeling? Have you had any other medical problems since your last visit?”)
- Observation by the investigational team, other healthcare providers, or relatives.

All adverse events occurring during the study period must be documented. The clinical course of each event should be followed until resolution, stabilization, or until it has been determined that the study treatment or participation is not the cause. Serious adverse events that are ongoing at the end of the study period must continue to be followed until the final outcome is determined. Any SAE occurring after the study period that is considered possibly related to the study intervention or participation must also be recorded and reported immediately.

A serious adverse event must be reported to the study sponsor within 24 hours of occurrence. The investigator must complete a SAE form and send it to the study sponsor by fax within 24 hours. A copy of the completed SAE form must be retained at the study site. SAEs should be reported to the sponsor promptly by telephone and facsimile.

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At the time of the initial report, the following information should be provided:

• Study identifier • Study Center • Subject number • A description of the event • Date of onset • Current status	• Whether study treatment was discontinued • The reason why the event is classified as serious • Investigator assessment of the association between the event and study treatment

The report should include a copy of the completed SAE form, along with any additional diagnostic information that may assist in understanding the event. Any significant new information regarding ongoing SAEs should be communicated promptly to the study sponsor.

6.3.1 Pregnancy

Pregnancy in a study participant is not considered an AE unless there is suspicion that the study intervention may have interfered with the effectiveness of a contraceptive method. Nevertheless, the outcome of all pregnancies—including spontaneous miscarriage, elective termination, normal birth, or congenital abnormality—must be followed up and documented, even if the participant has been discontinued from the study. All reports of congenital abnormalities or birth defects are classified as SAEs, and spontaneous miscarriages must also be reported and managed as SAEs. Elective abortions

without complications are not considered AEs. All pregnancy outcomes must be reported using the pregnancy outcomes report form.

Pregnancy of the participant's partner is not considered an AE. However, the outcome of all such pregnancies—including spontaneous miscarriage, elective termination, normal birth, or congenital abnormality—must also be followed up and documented. The outcomes of any conception occurring during the study must be recorded, and all pregnancy outcomes must be reported on the pregnancy outcomes report form.

6.3.2 Notification Procedure

- The SAE form must be completed by the Investigator (consultant named on the signature list and delegation of responsibilities log who is responsible for the participant's care), with careful attention to the grading, causality, and expectedness of the event as outlined above. In the absence of the responsible Investigator, the form should be completed and signed by another member of the site trial team.
- All unexpected SAEs not defined in the protocol or related documents in ENHT-sponsored trials (including non-ENHT participants) must be reported to the R&D Office using the ENHT Adverse Event Report Form, along with a copy of the local or trial-specific form used for REC/HRA notification.
- Initial SAE reports must be faxed within one working day of the Investigator becoming aware of the event.
- Participants must be followed up until clinical recovery is complete, laboratory results have returned to normal or baseline, or the event has stabilized. Follow-up should continue after completion of protocol treatment if necessary. Follow-up information should be recorded

on a further SAE form by ticking the box marked ‘follow-up’ as information becomes available. Additional annotated information or copies of test results may be provided separately. Participants must be identified only by trial number, date of birth, and initials; their full name should not be used on any correspondence.

6.3.3 Medical Monitoring

The PI is responsible for overseeing the safety of the study at their site. This includes careful assessment and appropriate reporting of adverse events, as described above, as well as the development and implementation of a site-specific data and safety monitoring plan. Medical monitoring will involve regular review of the number and type of SAEs and suspected unexpected serious adverse events.

6.3.4 Hospitalization, Prolonged Hospitalization or Surgery

Any adverse event that results in hospitalization or prolonged hospitalization should be documented and reported as a serious adverse event unless specifically instructed otherwise in this protocol. Any condition responsible for surgery should be documented as an adverse event if the condition meets the criteria for an adverse event.

Neither the condition, hospitalization, prolonged hospitalization, nor surgery should be reported as an adverse event under the following circumstances:

- Hospitalization or prolonged hospitalization for diagnostic or elective surgical procedures related to a pre-existing condition. Surgery should not be reported as an adverse event if it is elective or diagnostic and the outcome is uneventful.
- Hospitalization or prolonged hospitalization required solely for the purpose of efficacy assessments in the study.

- Hospitalization or prolonged hospitalization for treatment of the study's target disease, unless there is a clinically significant worsening or an increased frequency of hospital admissions, as determined by the clinical investigator.

Examples of events that are NOT to be reported as AEs:

- Medical or surgical procedures (e.g., endoscopy, appendectomy). *Note:* the underlying condition that necessitated the procedure is considered an AE.
- Situations in which no untoward medical occurrence occurred (e.g., social or convenience admission to a hospital).
- Anticipated day-to-day fluctuations of pre-existing disease(s) or condition(s) present or detected at study entry, provided they do not worsen.
- The disease or disorder under study, or expected progression, signs, or symptoms of the disease/disorder, unless these are more severe than would be expected for the participant's condition.

6.3.5 Post study AEs

All unresolved AEs should be followed by the investigator until the event is resolved, the participant is lost to follow-up, or the AE is otherwise explained. At the participant's final scheduled visit, the investigator should instruct the participant to report any subsequent events that they, or their personal physician, believe may reasonably be related to participation in the study. The investigator must notify the study sponsor of any death or AE occurring at any time after a participant has discontinued or terminated study participation if it may reasonably be related to the study. Additionally, the sponsor should be informed if the investigator becomes aware of the development of cancer or a congenital anomaly in a subsequently conceived offspring of a participant who took part in the study.

6.3.6 Abnormal Laboratory values

A clinical laboratory abnormality should be documented as an AE if any of the following conditions are met:

- The abnormality is confirmed by repeat testing and is not otherwise refuted.
- The abnormality suggests a disease and/or organ toxicity.
- The abnormality is of sufficient severity to require active management, such as modification of study intervention, more frequent follow-up assessments, or further diagnostic investigations.

Abnormal laboratory findings (e.g., clinical chemistry, hematology, urinalysis) or other abnormal assessments that the investigator judges to be clinically significant should be recorded as AEs or SAEs if they meet the definitions of an AE or SAE.

Clinically significant abnormal laboratory findings or other abnormal assessments that are detected during the study, or that are present at baseline and significantly worsen following study initiation, must be reported as AEs or SAEs. However, clinically significant abnormalities that are associated with the disease under study—unless judged by the investigator to be more severe than expected for the participant's condition—or abnormalities present at baseline that do not worsen, will not be reported as AEs or SAEs.

6.3.7 Lack of efficacy

When there is a deterioration in the condition for which the study treatment is being used, it may be unclear whether this represents a lack of efficacy or an AE. In such cases, unless the reporting physician determines that the study treatment contributed to the deterioration, or local regulations require otherwise, the deterioration should be classified as a lack of efficacy rather than an AE.

6.3.8 Deaths

All deaths occurring during the study, or within the protocol-defined follow-up period after administration of the last study intervention, must be reported as follows:

- Death clearly due to disease progression: This should be documented in the CRF and reported to the study monitor at the next monitoring visit. It should not be reported as a SAE.
- Death not clearly due to disease progression: The adverse event leading to death must be reported to the study monitor as an SAE within 24 hours. The report should indicate any co-involvement of disease progression, if applicable, and specify the main and contributory causes of death.
- Death of unknown cause: This must always be reported as an SAE. A post-mortem examination may be performed to assist in determining the cause of death.

7 STATISTICS AND DATA ANALYSIS

7.1 Sample Size determination

A priori power analysis was based on data from Tetteh et al. (12), which reported reductions in lumbar erector spinae activity from ~5.7%MVC to 3.8%MVC with exoskeleton use. Standard deviations were estimated at 35% of the mean, yielding a conservative effect size of $d \approx 0.6$ for intraoperative conditions. Using a paired design ($\alpha = 0.05$, 80% power), 24 participants were required. To account for potential data loss and variability, the final target sample size was set at 30 surgeons, each performing 30 procedures with and 30 without exoskeleton support, resulting in 60 operations in each arm of the study. In total, 180 operations will be performed.

7.2 Subject Population(s) for Analysis

A priori power analysis was informed by data from Tetteh et al. (12), which demonstrated a reduction in lumbar erector spinae activity from approximately 5.7% MVC to 3.8% MVC with exoskeleton use. Standard deviations were conservatively estimated at 35% of the mean, corresponding to an effect size of approximately $d \approx 0.6$ under intraoperative conditions. Based on a paired study design ($\alpha = 0.05$, 80% power), a minimum of 24 participants was required. To accommodate potential data loss and variability, the target sample size was increased to 30 surgeons. Each participant will perform 30 procedures with and 30 without exoskeleton support, yielding 60 operations per study arm and a total of 180 operations overall.

7.3 Statistic Methods

Data will be assessed for parametric conformation. Based on a previous study comparing effects of standard operating chair vs ergonomic chair during simulated microscopic procedures (4) where parametric assumptions were not met, we would then employ Wilcoxon signed-rank test for continuous data assessment of the difference in %rest sEMG and % max sEMG between cases using exoskeleton and those without exoskeleton.

8 DATA HANDLING AND RECORD KEEPING

8.1 Confidentiality

Information about study participants will be kept confidential and managed in accordance with Trust requirements. These requirements include a signed participant authorization, which informs participants of the following:

- Who will have access to their information and for what purpose.
- Who may use or disclose their information.
- The participant’s right to revoke their authorization at any time.

If a participant revokes their authorization, the investigator is, by regulation, permitted to use all information collected prior to the revocation. For participants who have revoked authorization, reasonable efforts should be made to obtain permission to collect at least vital status information (i.e., confirmation that the participant is alive) at the end of their scheduled study period.

8.2 Source Documents

Source data comprise all original information, records of clinical findings, observations, or other activities in a study that are necessary for the reconstruction and evaluation of the study. These data are contained in source documents. Examples of source documents and original records include hospital records, clinical and office charts, laboratory notes and memoranda, participant diaries or evaluation checklists, pharmacy dispensing records, recorded data from automated instruments, copies or transcriptions certified as accurate and complete, microfiches, photographic negatives, microfilm or magnetic media, x-rays, participant files, and records maintained at the pharmacy, laboratories, and medico-technical departments involved in the trial.

The source data for each study should be determined based on the study type and Trust policy and should be detailed in the study protocol. If the CRF is to be considered source data, this must be clearly specified in the protocol.

8.3 Case Report Form

The study CRF serves as the primary data collection instrument for the study. All data requested on the CRF must be recorded, and any missing data must be explained. If a field on the CRF is left blank because the procedure was not performed or the question was not asked, enter “ND” for not done. If the item is not applicable to the individual case, enter “NA.” All entries should be printed legibly in black ink. If an error is made, correct it by drawing a single line through the incorrect entry and entering

the correct data above it. All such corrections must be initialed and dated. DO NOT ERASE OR WHITE OUT ERRORS. For clarification of illegible or uncertain entries, print the clarification above the item, then initial and date it.

8.4 Data handling and record keeping

The Investigator and study personnel are required to maintain the confidentiality of any information provided by East and North Hertfordshire NHS Trust, including this protocol, as well as all data and records generated during the conduct of the study. Such information, data, and records may only be used for the purpose of conducting the study. These confidentiality obligations do not apply to information that becomes publicly available through no fault of the investigator or study personnel, information that must be disclosed in confidence to an Ethics Committee for the purpose of study evaluation, information that must be disclosed to provide appropriate medical care to a study participant, or study results that are published. If a written contract governing the conduct of the study is executed and contains confidentiality provisions that differ from this statement, the contract's provisions shall take precedence. The Chief Investigator is responsible for ensuring compliance with these requirements.

8.5 Records Retention

- Archiving for this study will be carried out in accordance with gSOP-17.
- Destruction of essential documents will require prior authorization from the Sponsor.
- Archiving will be authorized by the Sponsor following submission of the end-of-study report.
- The Sponsor will determine which trial documents it is responsible for archiving and which documents the study site(s) will retain.

- The location and duration of retention for essential documents and databases will be specified in the archiving plan.
- All essential documents will be archived for a minimum of five years following the completion of the trial.

9. STUDY MONITORING, AUDITING AND INSPECTING

9.1 Study Monitoring Plan

This study will be monitored in accordance with the monitoring plan, and the Investigator will allocate adequate time for all monitoring activities.

The Investigator will ensure that the monitor, or any compliance or quality assurance reviewer, has access to all study-related documents and facilities and is provided with adequate space to conduct monitoring visits.

The monitoring plan will depend on the type of trial, and the Sponsor will provide monitoring support as detailed in gSOP-12. Regardless of sponsor monitoring activities, the Investigator remains responsible for ensuring that all study data are accurate, verifiable, and that participant safety is maintained throughout the trial.

9.2 Auditing and Inspecting

The Investigator will allow study-related audits and inspections by the Independent Ethics Committee (IEC), the Sponsor, government regulatory authorities, and R&D Compliance and Quality Assurance groups of all study-related documents, including source documents, regulatory documents, data collection instruments, and study data. The Investigator will also ensure that all applicable study-related facilities, such as diagnostic laboratories, are accessible for inspection.

Participation as an Investigator in this study implies acceptance of potential inspections by government regulatory authorities, as well as R&D Compliance and Sponsor Quality Assurance offices.

9.3 Trial Management Group (TMG)

This will be comprised of the members stated above between East and North Herts NHS Trust and University of Hertfordshire.

10. REGULATORY OBLIGATIONS AND COMPLIANCE

This study will be conducted in accordance with European Union and international standards of Good Clinical Practice (GCP), International Council for Harmonisation (ICH) guidelines, applicable government regulations, and ethics policies and procedures.

This protocol, along with any amendments, will be submitted to a properly constituted Independent Ethics Committee (IEC), in accordance with local legal requirements, for formal approval of the study conduct. The IEC's decision regarding the conduct of the study will be provided in writing to the Investigator, and a copy of this decision will be forwarded to the Sponsor prior to the commencement of the study. The Investigator should provide the Sponsor with a list of IEC members and their affiliations.

- Before any site can enroll participants in the trial, the Chief Investigator, Principal Investigator, or their designee will apply for NHS confirmation of capacity and capability from the site's Research & Development (R&D) department.

10.1 Protocol compliance

Protocol deviations, non-compliances, or breaches are defined as any departures from the approved protocol:

- Prospective, planned deviations or waivers to the protocol are not allowed and must not be used. For example, it is not acceptable to enroll a participant who does not meet the eligibility criteria or other restrictions specified in the trial protocol.
- Accidental protocol deviations may occur at any time. These must be adequately documented on the relevant forms and reported immediately to the Chief Investigator and Sponsor.
- Deviations from the protocol that are found to occur repeatedly are unacceptable, require immediate corrective action, and could potentially be classified as a serious breach.

10.2 Notification of Serious Breaches to GCP and/or the protocol

A "serious breach" is defined as a breach that is likely to significantly affect:

(a) the safety or the physical or mental integrity of the trial participants; or
(b) the scientific value of the trial.

- The Sponsor must be notified immediately if any situation arises during the study conduct that meets this definition.

11. STUDY FINANCES

11.1 Funding Source

We have secured a small grant from the trust through research capability framework to purchase the exoskeleton. The University of Hertfordshire will loan their sEMG equipment and perform sEMG analyses.

11.2 Conflict

Any investigator who has a conflict of interest with this study (patent ownership, royalties, or financial gain greater than the minimum allowable by their institution, etc.) must have the conflict reviewed by a properly constituted Conflict of Interest Committee with a Committee-sanctioned conflict management plan that has been reviewed and approved by the study sponsor prior to participation in this study.

11.3 Subject Stipends or Payments

None.

12 INDEMNITY

The East and North Hertfordshire NHS Trust will provide indemnity. Details of insurance cover will be forwarded to the NRES recognized Ethics Committee for review.

13 PUBLICATION PLAN

The project will either be published in an ENT or ergonomic journal upon completion. Examples include Otology Neurotology, Clinical Otolaryngology, Laryngoscope or Applied Ergonomics.

14 REFERENCES

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APPENDICES

Appendix A Patient information sheet

Appendix B Participant information sheet

Appendix C Participant Consent form

Appendix D Data collection sheet