Our AI platform can accurately recognise the surgical phase and step in vestibular schwannoma resections…

Background

•Surgical management of vestibular schwannoma (VS) has evolved, significantly reducing morbidity and mortality but remains a complex and high-risk procedure.
•Challenges in VS resection include the low volume and high complexity of cases, and centralisation of expertise to centres of excellence, limiting training opportunities.
•Artificial intelligence (AI), particularly machine learning (ML), presents opportunities in surgical video analysis for training, auditing, decision support, and prognostication.
•Existing ML platforms for operative workflow analysis are limited to shorter surgeries (<2 hours) with minimal scene changes.

Aims

•To create a ML model capable of recognising operative phases and steps in lengthy, data-heavy VS surgeries.
•To advance ML-based surgical workflow prediction platforms by addressing unique challenges of complex, non-linear surgeries.

Methods

•Dataset:
- Operative videos from 21 microscopic retrosigmoid VS resections collected over three years at a single institution.
- Videos annotated into phases (Approach, Excision, Closure) and intra-phase steps (Debulking, Dissection) based on expert consensus.

•ML Model:
- Consisted of a convolutional neural network (CNN) followed by a recurrent neural network (RNN).
- Performance evaluated using 5-fold cross-validation.
- Metrics assessed: accuracy, precision, recall, and F1 score for phase and step prediction tasks.

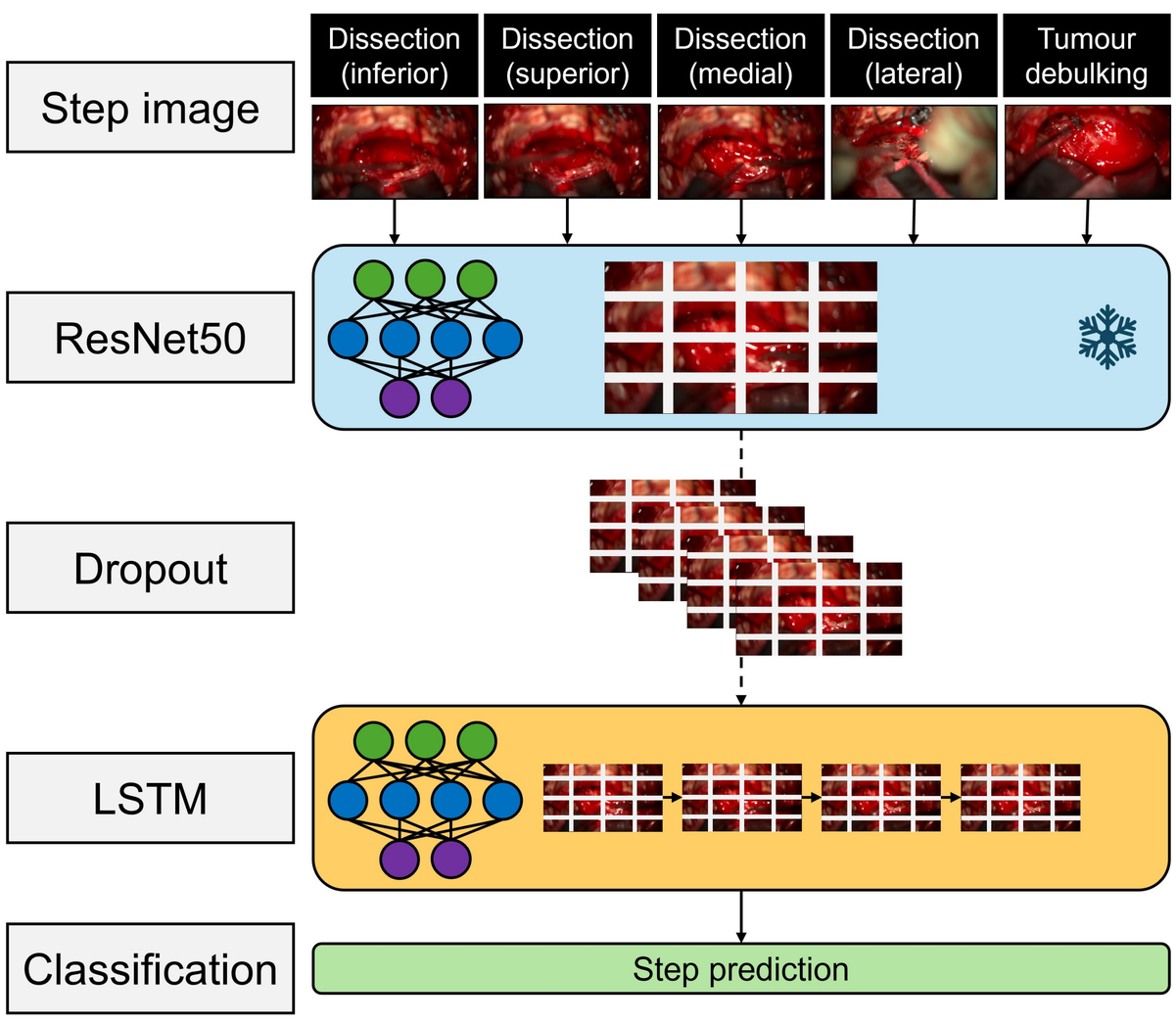

Figure 1: Typical operative Images for each surgical phase, and a typical time plot showcasing the duration of each phase and the interchange between steps within the 'Tumour Excision' phase.

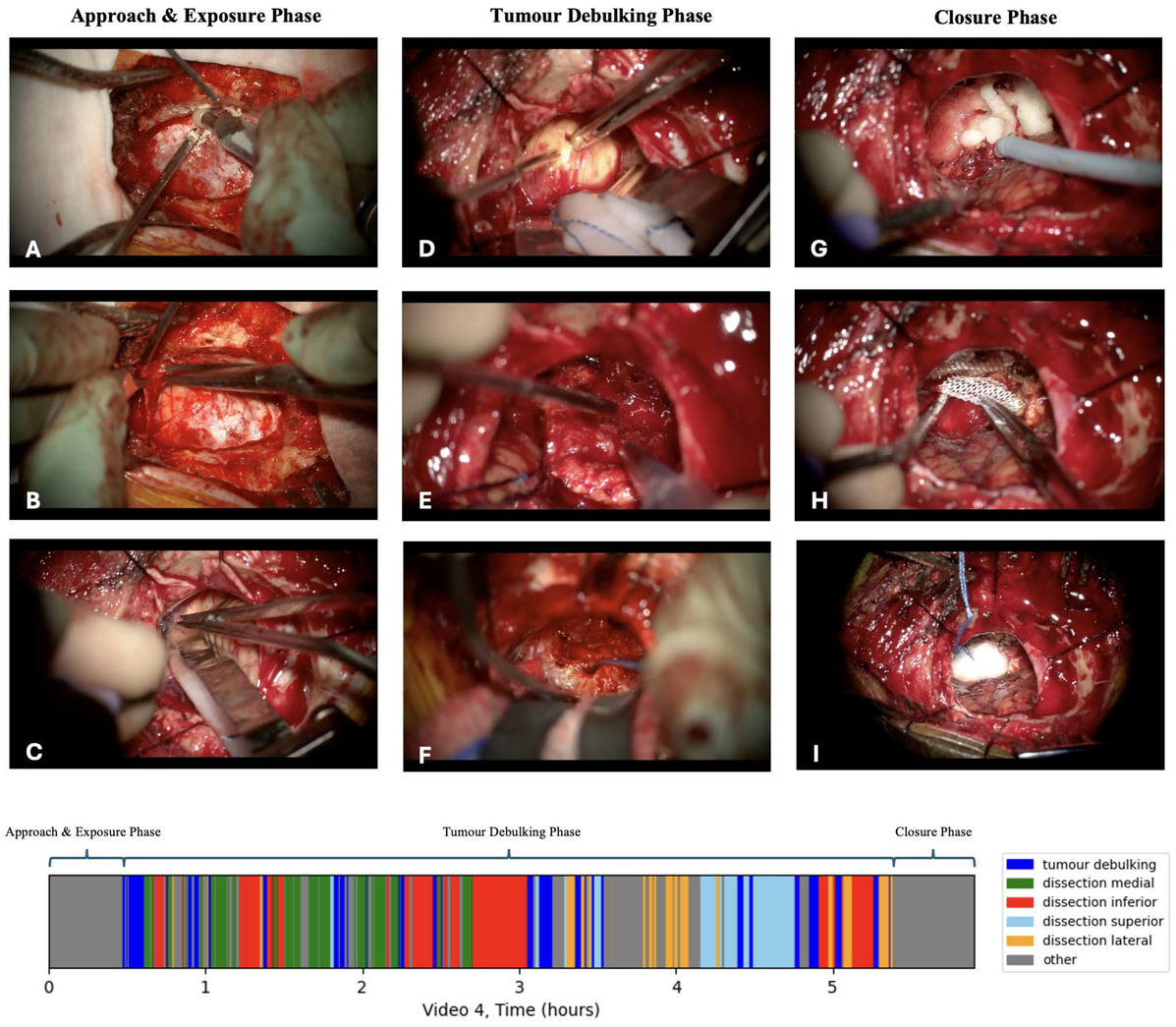

Figure 2: Overview of video processing architecture incorporating ResNet50 and Long Short-Term Memory platforms layers.

Results

•Median operative video duration: 5 hours 18 minutes (IQR 3hr 21min–6hr 1min).
- Tumour Excision phase: Median 4hr 23min.
- Approach and Exposure phase: Median 28min.
- Closure phase: Median 17min.

•ML model performance:
- Phase prediction: Accuracy 81%, weighted F1 0.83.
- Dichotomised step prediction: Accuracy 86%, weighted F1 0.86.
- Individual step prediction: Accuracy 59%, weighted F1 0.58.

Conclusion

•The CNN-RNN model effectively predicts surgical phases and dichotomised steps in retrosigmoid vestibular schwannoma resection, with reduced accuracy for individual steps.
•Key contributions:
- Addresses challenges in ML analysis of extensive datasets for lengthy procedures.
- Navigates non-linear surgical workflows with specific phase transitions.

•Future ML applications in low-volume complex surgeries should focus on collaborative video sharing to overcome early technical barriers for clinical translation.

Why Does This Matter?!

AI applications in surgery are currently limited in application. However, automated operative video analysis holds the possibility for numerous potential applications.

- **Improved Surgical Training**: Automated workflow analysis provides objective feedback to trainees, enhancing skill acquisition and accelerating the learning curve for complex procedures.
- **Enhanced Patient Safety**: By identifying workflow deviations and reducing errors, this technology can minimise complications during high-risk surgeries.
- **Real-Time Decision Support**: Context-aware systems can assist surgeons during operations, providing guidance on the next steps and improving intraoperative decision-making.
- **Operational Efficiency**: Accurate phase and step recognition can optimise resource allocation, improve operating room turnover, and streamline scheduling.
- **Standardised Skill Assessment**: Objective metrics derived from video analysis enable consistent evaluation of surgical performance, benefiting training, accreditation, and revalidation.
- **Data-Driven Research**: Large-scale analysis of surgical workflows can reveal patterns that inform best practices and refine surgical techniques globally.

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Automated Operative Workflow Recognition in Vestibular Schwannoma Resection: Development and Preclinical Evaluation of a Deep Learning Neural Network (IDEAL stage 0)

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