

Transaxillary valve surgery: innovation through simplicity in minimally invasive cardiac surgery

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Abstract: Minimally invasive cardiac surgery (MICS) is widely recognized as an essential component of contemporary cardiac surgical practice, offering reduced surgical trauma, faster recovery, and improved patient satisfaction while maintaining excellent clinical outcomes. Nevertheless, despite decades of technological progress and growing clinical evidence, its adoption remains limited. One of the principal barriers to wider dissemination is the procedural complexity associated with many minimally invasive platforms. Reduced operative exposure, indirect visualization, and dependence on dedicated technology frequently result in demanding workflows, prolonged learning curves, and limited reproducibility. The right transaxillary mini-thoracotomy direct vision approach was developed according to a different philosophy. Rather than relying on additional technology to compensate for the constraints of minimally invasive access, it simplifies the operative platform by preserving the natural interaction between the surgeon and the operative field. By combining favorable surgical geometry, direct visualization, and a standardized operative platform, the transaxillary approach facilitates procedural efficiency, reproducibility, and potential applicability across a broad spectrum of minimally invasive valve surgery while relying primarily on conventional surgical instrumentation. More broadly, the transaxillary concept suggests that the future dissemination of MICS may depend not only on technological innovation, but also on the ability to simplify procedural execution, facilitate reproducibility, and lower the barriers to adoption.

Keywords: Minimally invasive cardiac surgery (MICS); transaxillary valve surgery; direct view; innovation



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Introduction

Over the past three decades, minimally invasive cardiac surgery (MICS) has evolved from a niche innovation into an established component of contemporary cardiac surgical practice. Numerous studies have demonstrated that minimally invasive approaches provide clinical outcomes comparable to conventional sternotomy while reducing surgical trauma, accelerating postoperative recovery, shortening hospital stay, and improving patient satisfaction (1-6).

Despite these well-established benefits, adoption of MICS remains surprisingly limited. National registry data from the United States and the Netherlands indicate that minimally invasive approaches are still used in a minority of mitral valve procedures. In Germany, national reports suggest broader adoption of minimally invasive techniques

for single-valve surgery; however, comparable data for combined procedures are not available (7-10).

This discrepancy reveals a fundamental paradox. Although minimally invasive surgery is widely recognized as the preferred strategy for reducing surgical trauma, it has not become the default approach for most patients. If MICS truly represented the standard of care, conventional sternotomy would be reserved for selected indications rather than remaining the predominant surgical access.

The principal obstacle is no longer the demonstration of clinical benefit, but the technical complexity associated with many minimally invasive platforms. Limited exposure, indirect visualization, altered visuomotor interaction and dependence on advanced technology may result in procedures that are technically demanding, difficult to reproduce and associated with prolonged learning curves.

This observation suggests that the next evolution of MICS may not depend on increasingly sophisticated technology, but on simplifying the interaction between the surgeon and the operative field. The most effective innovation is not necessarily the one that adds complexity, but the one that removes it.

The transaxillary approach was developed according to this philosophy. Rather than adapting the surgeon to a technologically mediated environment, it preserves many of the visual, anatomical, and ergonomic characteristics of conventional surgery while maintaining the advantages associated with minimally invasive access.

Rethinking innovation: from technology to simplicity

The evolution of MICS has largely been driven by technological innovation. High-definition endoscopic imaging, three-dimensional visualization, and robotic platforms have progressively expanded the feasibility of performing increasingly complex cardiac procedures through progressively smaller incisions (11-16).

These advances have transformed the field and significantly broadened the therapeutic possibilities of minimally invasive surgery. However, technological progress has often been accompanied by increasing procedural complexity. Indirect visualization, dedicated instrumentation, platform-dependent workflows and substantial capital investment may contribute to longer learning curves, greater technical variability and limited dissemination beyond highly specialized centers.

This raises an important question: what should define the next generation of innovation in MICS?

One possible direction is the continued development of increasingly sophisticated technologies to overcome the limitations imposed by smaller surgical access. An alternative approach is to redesign the surgical platform itself, minimizing the need for technological compensation by restoring a more natural interaction between the surgeon and the operative field.

Simplification of procedural workflow may represent an important driver of dissemination. Surgical innovations that reduce technical barriers while preserving safety, reproducibility, and effectiveness are more readily adopted, more easily taught, and more consistently integrated into routine clinical practice (17).

Within this perspective, simplicity should not be interpreted as the absence of innovation, but as one of its highest expressions. A successful surgical innovation is

Innovation through simplicity

Two different innovation strategies toward the same destination

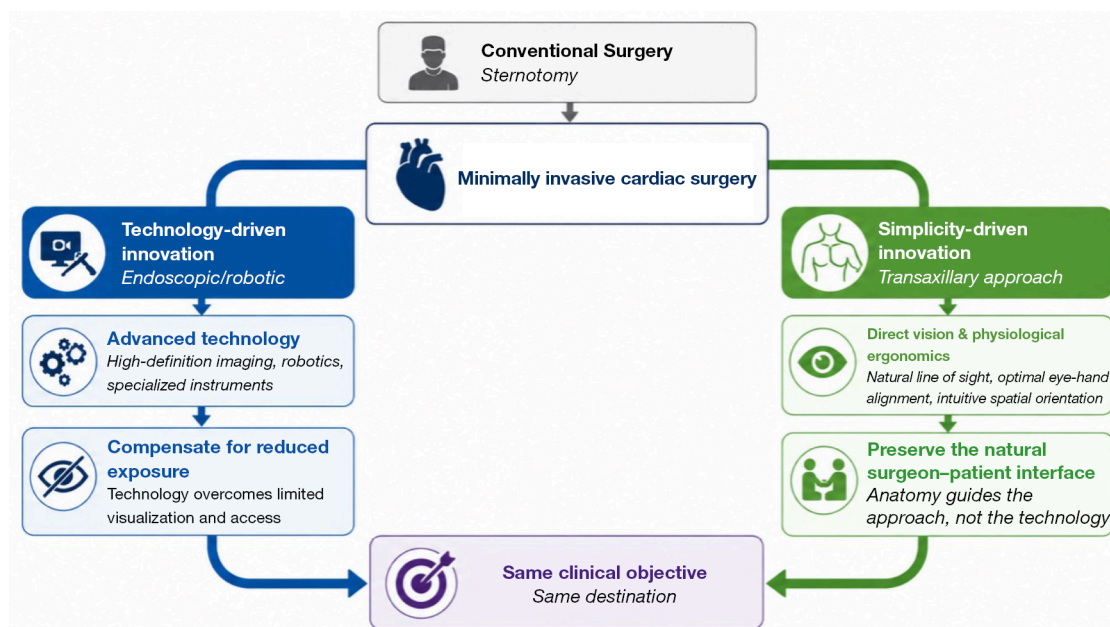


Figure 1 Two conceptual pathways toward minimally invasive cardiac surgery. Technology-driven innovation compensates for reduced exposure through advanced technology, while the transaxillary approach aims to preserve a more familiar surgeon-patient interface. Both strategies pursue the same goal through fundamentally different philosophies.

not necessarily the one that introduces the greatest amount of technology, but the one that removes unnecessary complexity from the procedure. The transaxillary approach embodies this (*Figure 1*).

Concept and evolution of the transaxillary approach

In 2018, our group initiated a strategic transition from endoscopic-assisted right minithoracotomy to a transaxillary direct vision approach.

Endoscopic surgery represented a pivotal step in the evolution of MICS and significantly expanded the feasibility of complex valve procedures. Nevertheless, our experience progressively highlighted several practical limitations that could hinder broader adoption, including dependence on video systems, indirect visualization, dedicated instrumentation and the need for specific training and adaptation.

The transaxillary approach was therefore conceived with a different objective. Rather than further refining endoscopic surgery through additional technology, the goal was to simplify the surgical platform itself while preserving the established benefits of minimally invasive access.

This objective was pursued by preserving a more natural interaction between the surgeon and the operative field. Direct visualization, conventional instrumentation and favorable anatomical alignment provide an operative environment that retains many

characteristics of conventional surgery while maintaining the benefits associated with minimally invasive access (18-20).

Thus, the transition from an endoscopic-assisted approach to a transaxillary direct vision platform represented more than a technical modification. It marked a conceptual shift—from technology-driven adaptation toward simplicity-driven design.

Direct vision, cognitive ergonomics and the expanded operative comfort zone

Technical performance in surgery depends on far more than image quality alone. It reflects the efficiency of the entire surgeon-system interface, encompassing visual perception, spatial orientation, depth perception, hand-eye coordination and instrument manipulation.

Modern endoscopic and robotic platforms provide outstanding visualization and have greatly expanded the possibilities of MICS. However, they also require the surgeon to interact with the operative field through a technologically mediated interface. Visual information is acquired from a remote monitor, while manual actions are performed within a different spatial reference frame. Even with high-definition three-dimensional imaging, continuous visuomotor translation is required.

This additional processing represents a source of cognitive workload that is independent of the surgical procedure itself. Increasing evidence suggests that excessive cognitive burden influences technical performance, learning efficiency, and intraoperative decision-making (21-23).

For the transaxillary direct vision platform, the surgeon-system interface remains fundamentally different. Visual perception, manual actions and anatomical orientation remain naturally aligned throughout the procedure. Direct three-dimensional vision, preserved depth perception, and conventional instrumentation provide an operative environment that closely resembles conventional sternotomy despite the minimally invasive access. The primary surgeon operates under direct vision, while in our practice a head-mounted camera provides the surgical team and trainees with a shared view of the operative field, supporting teaching, recording, and postoperative review.

Because the platform itself may require less cognitive adaptation, a greater proportion of the surgeon's attentional resources may be devoted to procedural planning, technical execution and intraoperative decision-making rather than to the management of the interface (*Figure 2*).

This concept is reflected in what may be described as an expanded operative comfort zone.

Progress in surgery inevitably requires moving beyond one's comfort zone. However, the size of that initial zone is determined not only by surgical experience but also by the characteristics of the operative platform.

Within this conceptual framework, conventional sternotomy provides the largest operative comfort zone because it preserves the environment in which every cardiac surgeon is trained. Camera-mediated minimally invasive platforms may reduce that comfort zone by requiring additional cognitive adaptation. By preserving the natural surgeon-patient interface, the transaxillary direct vision platform may expand the

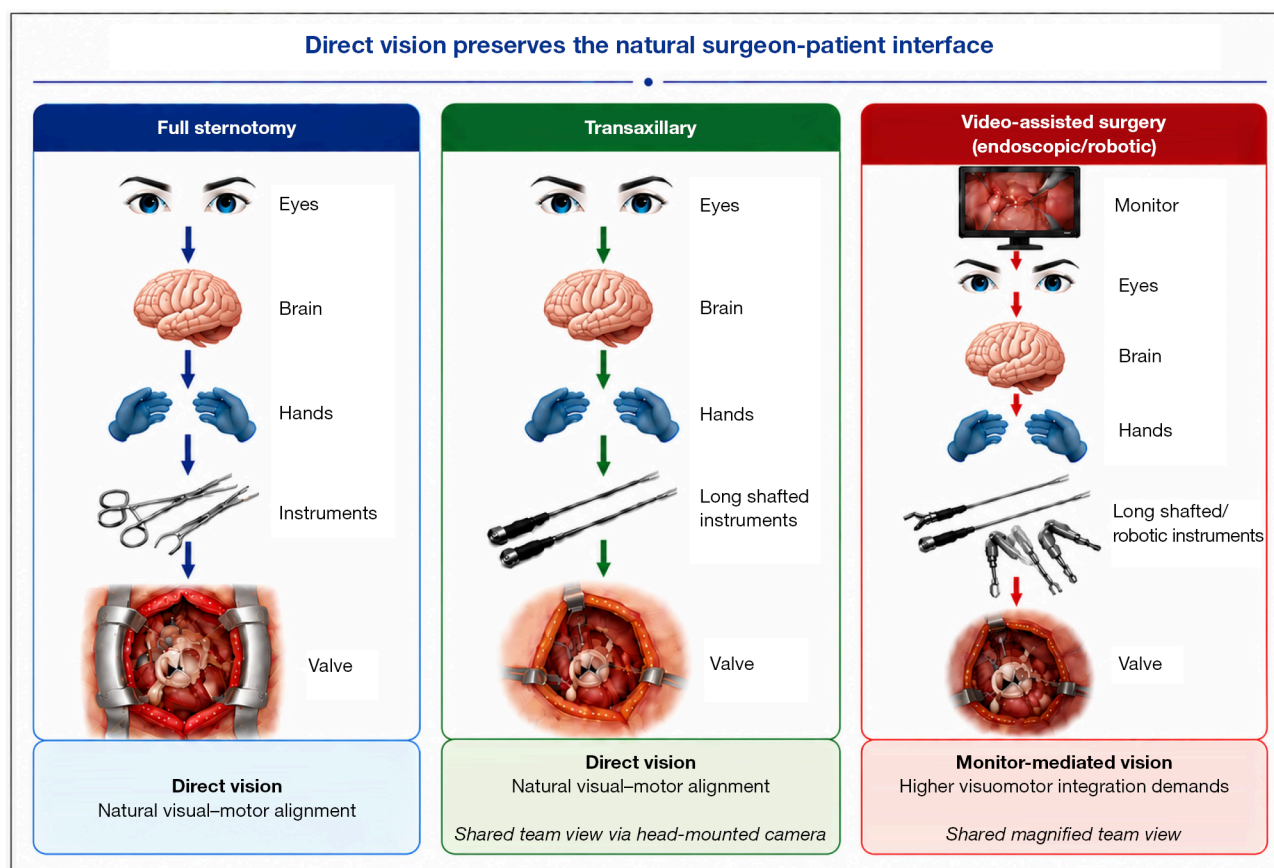


Figure 2 Comparison of the surgeon-patient interface in full sternotomy, transaxillary, and video-assisted surgery. Full sternotomy and transaxillary surgery rely on direct vision and preserve natural visual-motor alignment. In the transaxillary approach, a head-mounted camera can provide a shared view of the operative field for the surgical team and trainees. Video-assisted endoscopic and robotic platforms rely on monitor-mediated vision, which involves higher visuomotor integration demands while providing a shared, magnified operative view that may facilitate team visualization and teaching.

operative comfort zone while maintaining the advantages associated with minimally invasive surgery.

Rather than eliminating the learning curve, the transaxillary platform may reduce the cognitive distance between conventional and minimally invasive surgery. In our experience, earlier procedural confidence, greater reproducibility, and broader dissemination may represent practical consequences of this design.

Importantly, these potential advantages may extend beyond the initial learning phase. As procedural complexity increases, reducing the cognitive demands imposed by the surgical platform may allow greater mental resources to be devoted to operative strategy, judgment and decision-making. In our experience, this may be particularly relevant during complex valve repair, multivalve surgery and combined procedures.

Geometric and anatomical foundations

The advantages of the transaxillary direct vision platform are not solely the consequence of direct visualization. They originate from the combination of favorable surgical geometry and the intrinsic orientation of cardiac anatomy.

Rather than compensating for limited exposure through additional technology, the transaxillary approach exploits the natural anatomical relationship between the heart and the right lateral thoracic wall to create favorable operative conditions.

Three geometric principles define the platform:

- I. Perpendicular orientation to the valve plane;
- II. Short working distance between the surgeon and the operative target;
- III. Coaxial alignment of vision and surgical instrumentation.

These principles are not artificially created but arise from the generally favorable relationship between the cardiac valve planes and the right lateral thoracic wall. Although this relationship varies according to individual anatomy and the intended procedure, the transaxillary approach can provide a direct and well-aligned trajectory to the mitral, aortic and tricuspid valves (*Figure 3*).

In our current practice, access is obtained through a 4–5 cm incision along the right anterior axillary line, generally through the third or fourth intercostal space. Intercostal-space selection is guided by preoperative CT assessment of patient-specific anatomy,

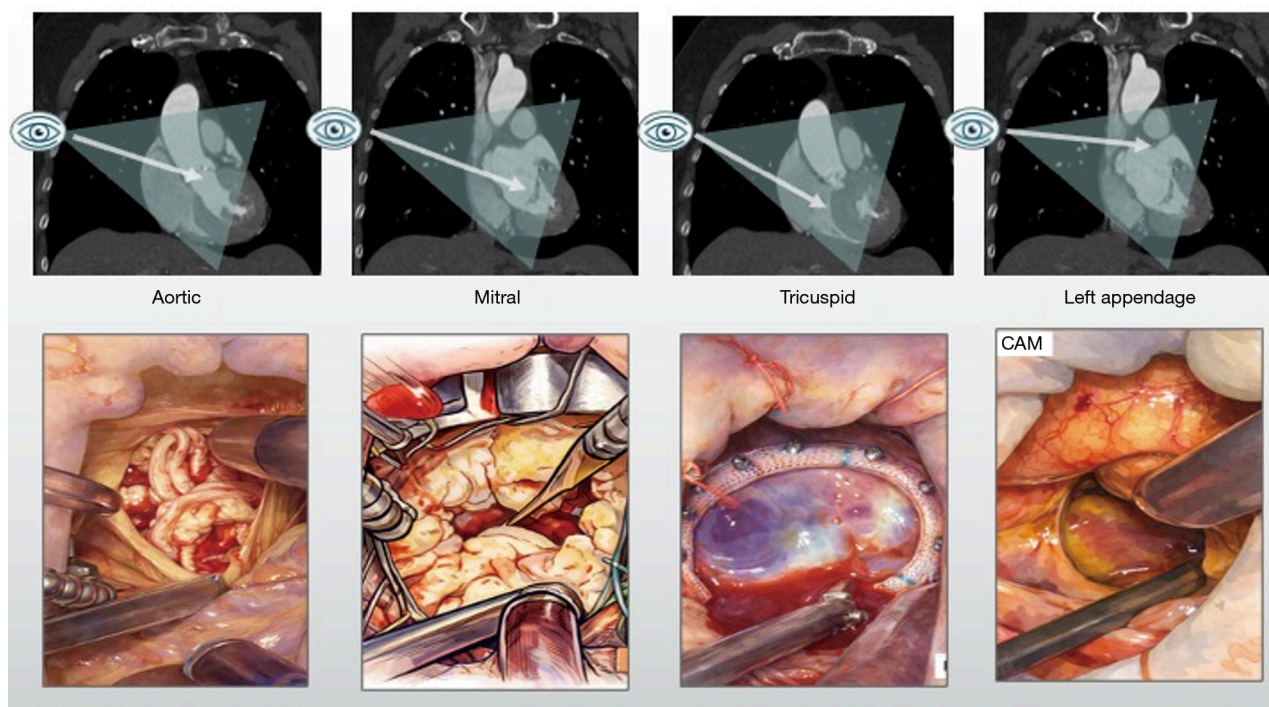


Figure 3 Natural anatomical alignment of the transaxillary platform. The transaxillary platform exploits the generally favorable relationship between the cardiac structures and the right lateral thoracic wall. Depending on individual anatomy and the intended procedure, this alignment can provide direct vision, near-perpendicular access to the target, coaxial vision-instrument alignment, and a short working distance achieved through pericardial traction.

including target valve-plane orientation, working distance, aortic trajectory and diaphragmatic height, with particular relevance for aortic and multivalvular procedures. These criteria are described in detail in a dedicated technical contribution to this Special Issue (24). A minithoracotomy retractor is used selectively during initial exposure, followed by a soft-tissue retractor. A key technical component is the placement of seven pericardial stay sutures, secured directly to the skin at the level of the incision. Traction on these sutures displaces the heart toward the thoracic wall and reduces the working distance to approximately 8–12 cm while maintaining direct exposure (20).

The result is an operative field that preserves many of the spatial relationships familiar from conventional sternotomy despite the substantially smaller incision. Rather than forcing the surgeon to adapt to the access, the access is designed around the native anatomy.

A unified operative platform

The geometric principles described above generate an additional advantage: a unified operative platform within the thoracic cavity.

Rather than providing access to a single anatomical structure, the transaxillary approach places the surgeon in a central position from which all major cardiac targets can be reached through short, direct and balanced working distances. From the same incision, the ascending aorta, superior and inferior vena cava, right atrium, pulmonary veins, left atrium, mitral valve, aortic valve, tricuspid valve and left atrial appendage are all accessible without changing surgeon position, patient orientation or operative setup.

This central positioning forms the anatomical basis for the versatility of the platform.

The transaxillary approach should therefore not be regarded as a dedicated access for individual valve procedures, but as a unified operative platform for MICS. The core principles of exposure, visualization, instrumentation and surgeon positioning remain consistent across procedures, although the selected intercostal space and selected technical details may be adapted according to the target anatomy and individual patient characteristics.

Only the anatomical target changes. The platform does not.

This consistency may simplify operative workflow, reduce procedural variability and facilitate increasingly complex procedures, including double-valve and triple-valve operations, atrial fibrillation ablation and left atrial appendage management, without requiring a different surgical strategy.

Operative efficiency and clinical implications

One of the most clinically relevant features of the transaxillary approach is its potential to improve operative efficiency.

Direct vision, optimized surgical geometry, and preserved visuomotor coordination allow procedures to be performed with cardiopulmonary bypass and aortic cross-clamp times approaching those of conventional sternotomy while remaining substantially shorter than many video-assisted techniques.

Evidence from the Mini-Mitral International Registry demonstrated that direct-vision minimally invasive procedures are associated with significantly shorter cross-

clamp times than video-assisted approaches, approaching those achieved through median sternotomy (25).

As direct vision represents a defining feature of the transaxillary platform, these findings are particularly relevant to its potential operative efficiency, while operative times may also be influenced by patient selection, procedural complexity, and institutional experience. This observation has important clinical implications.

Cross-clamp duration is consistently associated with postoperative mortality, acute kidney injury, myocardial dysfunction and low cardiac output syndrome. Therefore, every reduction in procedural time has the potential to translate into improved perioperative outcomes (25).

Beyond patient safety, greater operative efficiency expands the indications for minimally invasive surgery. In our experience, the transaxillary platform has facilitated the performance of increasingly complex procedures, including multivalve operations, extensive valve repair, root enlargement and combined procedures.

Shorter and more predictable procedures may also simplify perioperative management.

Anesthesiologists are more likely to adopt fast-track strategies, including immediate extubation in the operating room, when operative duration is limited and intraoperative conditions remain stable. This observation is consistent with our own clinical experience, where on-table extubation has become routine in most patients undergoing transaxillary valve surgery (6,18,20).

Finally, operative efficiency influences not only patient outcomes but also institutional acceptance.

Predictable operative times, standardized workflows and reduced technical variability improve team confidence, facilitate operating room scheduling and encourage the progressive implementation of minimally invasive programs.

Accessibility, scalability and reproducibility

The characteristics described in the previous sections have implications that extend well beyond the individual surgical procedure. By combining a familiar operative environment with a standardized surgical platform, the transaxillary approach may create favorable conditions for broader dissemination of MICS.

Implementation of a minimally invasive program depends not only on surgical expertise, but also on the complexity of the operative platform itself. Surgical techniques that preserve familiar workflows and require limited adaptation may lower barriers to adoption and facilitate integration into routine clinical practice. Published experience with the transaxillary approach suggests that familiarity with conventional surgical principles may facilitate the transition to this platform (26). The transaxillary direct vision platform was developed with these principles in mind. Rather than requiring surgeons to acquire an entirely new operative strategy, it allows many of the technical skills developed during conventional surgery to be transferred directly to a minimally invasive setting.

Accessibility is further enhanced by the limited need for dedicated technology. The procedure relies primarily on standard surgical instruments and conventional operating

room infrastructure, reducing both economic barriers and dependence on specialized equipment.

Conclusions

The transaxillary approach represents more than an alternative minimally invasive access. It proposes a different way of thinking about innovation in cardiac surgery.

For many years, progress in minimally invasive surgery has been driven by technologies designed to compensate for the limitations imposed by smaller surgical incisions. The transaxillary concept follows a complementary path. Rather than adding complexity to overcome technical constraints, it redesigns the operative platform to preserve the natural interaction between the surgeon and the patient.

This philosophy extends beyond a single surgical approach. It suggests that the future dissemination of MICS will depend not only on technological advances but also on the ability to simplify procedural execution, facilitate reproducibility, and lower the barriers to adoption without compromising surgical quality.

Future multicenter studies comparing the transaxillary approach with established endoscopic and robotic platforms will be important to further assess operative efficiency, clinical outcomes, reproducibility, and educational implications. Such studies are particularly warranted because the current evidence is derived predominantly from observational series and experienced centers, and its generalizability across different institutions and stages of program development remains to be established. Nevertheless, if minimally invasive valve surgery is to evolve from a specialized technique into the standard surgical strategy for most patients, procedural simplicity may prove to be its most important enabling technology.

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Footnote

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