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# Implementation of Thulium Laser En Bloc Resection of Bladder Tumors at a Tertiary Care Center: Initial Experience and Learning Curve

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## Abstract

# Background:

Transurethral resection of bladder tumors (TURBT) remains the standard treatment for non-muscle-invasive bladder cancer (NMIBC), serving both diagnostic and therapeutic purposes. However, conventional resection may result in fragmented specimens, thermal artefact, obturator reflex, and challenges in pathological assessment. Thulium laser en bloc resection (ERBT) has emerged as an alternative approach with potential advantages in specimen integrity, controlled tissue interaction, and improved visualization.

# Objectives:

To evaluate feasibility, perioperative outcomes, pathological quality indicators, and implementation learning curve during initial adoption of thulium laser en bloc resection at a tertiary care center.

# Methods:

This prospective observational implementation study included 55 patients with 75 bladder tumors undergoing Thulium laser en bloc resection between April 2024 and December 2025. Data collection was protocolized before enrolment of the first patient and predefined perioperative, pathological, and postoperative variables were prospectively recorded. All procedures were performed by a single surgeon to maintain procedural consistency during implementation. Primary outcomes included operative efficiency, detrusor muscle detection, thermal artefact, and perioperative complications. Secondary outcomes included catheterization duration and hospital stay.

# Results:

The mean patient age was 60 ± 12 years and 85.5% of patients were male. Progressive improvement in operative efficiency and pathological quality indicators was observed across chronological implementation groups. Mean operative time decreased over the study period, while detrusor muscle detection improved from early to later phases of implementation. Thermal artefact rates reduced with increasing experience. No clinically significant obturator reflex or bladder perforation was observed. One patient required intervention for postoperative bleeding.

# Conclusions:

Initial implementation of thulium laser en bloc resection demonstrated feasibility and acceptable perioperative outcomes with progressive process stabilization and improvement in pathological quality

indicators. Structured adoption and standardized operative technique may facilitate implementation of this technology in tertiary practice settings.

# INTRODUCTION

Bladder cancer remains one of the most common urological malignancies worldwide, with non-muscle-invasive bladder cancer (NMIBC) accounting for the majority of newly diagnosed cases[1]. Transurethral resection of bladder tumors (TURBT) remains the cornerstone of diagnosis and management and provides both therapeutic and pathological information.

Despite widespread use, conventional TURBT has recognized limitations including specimen fragmentation, thermal artefact, obturator nerve reflex, risk of bladder perforation, and difficulty obtaining intact specimens containing adequate detrusor muscle for staging[2].

En bloc resection techniques have been introduced to address some of these limitations by enabling retrieval of the lesion in a more intact manner while preserving tissue architecture. Among available technologies, Thulium laser has attracted increasing interest because of continuous-wave emission, precise cutting characteristics, shallow penetration depth, and favorable haemostatic properties[3].

Several studies and recent systematic reviews have reported improved specimen integrity, higher rates of detrusor muscle identification, and lower perioperative morbidity with laser-assisted en bloc approaches compared with conventional resection techniques. However, evidence describing early implementation and workflow adaptation in centers adopting this technology remains limited[2,3].

Understanding implementation dynamics is important because successful adoption involves not only technical performance but also procedural standardization, patient selection, pathological workflow, and perioperative coordination.

The present study describes the initial implementation experience of thulium laser en bloc resection at a tertiary care center and evaluates perioperative outcomes, pathological quality indicators, and evolution of operative efficiency during the learning phase.

# MATERIALS AND METHODS

### Study Design and Ethics

This prospective observational implementation study was conducted between April 2024 and December 2025 to evaluate feasibility and early outcomes of thulium laser en bloc resection of bladder tumors.

Data collection was protocolized before enrolment of the first patient and predefined perioperative, pathological, and postoperative variables were prospectively recorded.

The study was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants.

**Patient Selection**

**Inclusion Criteria:**

- Patients aged ≥18 years
- Endoscopically or radiologically detected urinary bladder mass
- Tumors considered amenable to endoscopic en bloc resection
- Tumor size <4 cm
- Fitness for anesthesia and endoscopic surgery
- Written informed consent

**Exclusion Criteria:**

- Refusal to participate
- Tumors unsuitable for safe en bloc dissection
- Broad-based tumors with anticipated inability to retrieve specimen appropriately
- Cases with anticipated need for alternative resection strategy due to anatomical considerations

**Surgical Technique**

All procedures were performed under spinal anesthesia in lithotomy position using a standard 26 Fr continuous-flow resectoscope.

A Quanta Cyber TM Thulium laser system (2013 nm) with a 600-μm fiber was used in continuous-wave mode.(Table 1)

A fixed power setting of 30 W was selected based on published experience suggesting an acceptable balance between cutting efficiency and minimization of thermal tissue injury[4].

Although implementation occurred at the departmental level, all procedures included in this initial series were performed by a single surgeon to maintain procedural consistency during adoption of the technique. The surgeon had prior experience performing more than 100 conventional bipolar TURBT procedures before introduction of thulium laser ERBT.

After cystoscopic assessment, circumferential marking was performed around the lesion and dissection progressed within the appropriate plane until complete tumor mobilization.

Tumors ≤3 cm were preferentially retrieved intact. Tumors >3 cm underwent standardized retrieval after completion of en bloc dissection using controlled fragmentation only when required.

Conversion to conventional TURBT was predefined in cases of inability to maintain safe dissection, inadequate visualization, uncontrolled bleeding, or inability to retrieve the specimen.

All pathological specimens underwent evaluation by experienced uropathologists blinded to chronological case sequence.

**Outcome Measures**

Primary outcomes included:
- Operative efficiency
- Detrusor muscle detection
- Thermal artefact
- Perioperative complications

Secondary outcomes included:
- Catheterization duration
- Hospital stay

Thermal artefact was defined as heat-related tissue distortion sufficient to interfere with pathological interpretation.

High-quality specimen was defined as preserved tissue architecture with identifiable detrusor muscle and minimal thermal distortion permitting confident pathological assessment[5].

**Statistical Analysis**

Continuous variables were reported as mean ± standard deviation and categorical variables as frequencies and percentages.

Learning curve evaluation was performed using chronological grouping of cases and assessment of operative efficiency and pathological indicators.

Statistical analysis was performed using SPSS version 25.0 with $p<0.05$ considered statistically significant.

# RESULTS

**Patient Demographics and Baseline Characteristics**

A total of 55 patients with 75 bladder tumors underwent thulium laser en bloc resection during the study period. The baseline characteristics are summarized in Table 2.

The mean patient age was 60 ± 12 years (range 38–85 years), and most patients were male (85.5%). Smoking exposure was common and present in 83.6% of patients.

Comorbid conditions were frequently observed. COPD was present in 54.5% of patients, likely reflecting the substantial smoking burden within the study population. Diabetes mellitus and hypertension were

each present in 30.9% of patients.

**Tumor Characteristics**

Tumor characteristics are detailed in Table 3. Among 55 patients, 35 (63.6%) presented with a single lesion and 20 (36.4%) had two tumors.

Of the 75 tumors treated, 72 (96%) measured ≤3 cm and 3 tumors (4%) measured >3 cm.

Tumor distribution included posterior wall, dome, anterior wall, lateral wall, and posterolateral wall locations. Papillary morphology predominated (92%).

**Histopathological Outcomes**

Histopathological analysis demonstrated predominantly non-muscle-invasive disease.

T1 lesions represented the most common pathological stage, followed by Ta disease. Three patients demonstrated muscle-invasive disease (T2). Benign lesions and PUNLMP comprised a minority of cases.

All pathological assessment was performed by experienced uropathologists blinded to chronological case sequence.

Patients diagnosed with T1 disease underwent repeat transurethral resection (re-TURBT) according to institutional protocol and guideline-based practice. Re-TURBT findings were not included in implementation learning analyses.

**Learning Curve and Operative Efficiency**

Progressive improvement in operative efficiency was observed across chronological implementation groups.(Table 4)

Mean operative time decreased across successive case groups, with the greatest improvement occurring during early implementation.

Reduction in operative variability over time suggested increasing procedural standardization and adaptation to the operative workflow.

**Pathological Quality Indicators**

Progressive improvement in specimen quality was observed throughout implementation.

Detrusor muscle detection improved from 60% in early cases to 95% in later cases.

Thermal artefact declined from 40% in initial cases to 7.5% during later implementation phases.

High-quality specimen rates increased over time, reflecting improved identification of tissue planes and procedural consistency.

**Perioperative Outcomes and Safety**

No clinically significant obturator reflex was observed during the study period.

No bladder perforation occurred.

One patient required re-intervention for postoperative bleeding.

Mean hospital stay was 29.3 ± 7.8 hours and mean catheterization duration was 22.4 ± 5.6 hours.

These findings suggest acceptable perioperative outcomes during early implementation of the technique.

# DISCUSSION

This study presents the initial implementation experience of thulium laser en bloc resection at a tertiary care center and demonstrates progressive improvement in operative efficiency and pathological quality indicators during early adoption.

Rather than representing isolated acquisition of technical skill, the observed learning curve likely reflects adaptation to a new operative workflow, increased familiarity with laser–tissue interaction, optimization of procedural steps, and improved recognition of dissection planes.

**Implementation and Operative Evolution**

The most notable observation was progressive reduction in operative duration across chronological groups.

The largest improvements occurred during early implementation, after which performance became more stable, suggesting process standardization rather than continued major procedural modification.

**Pathological Quality and Tissue Preservation**

The observed reduction in thermal artefact and progressive increase in high-quality specimen rates over the implementation period likely reflect improved familiarity with laser–tissue interaction, optimization of operative technique, and better identification of dissection planes.

Progressive improvement in detrusor muscle detection (from 60% to 95%) was observed across chronological case groups. As detrusor muscle presence is considered an important quality indicator of bladder tumor resection and contributes to accurate pathological staging, this finding may indicate improved procedural consistency during implementation[6,7].

Improved preservation of specimen architecture may facilitate pathological interpretation and support clinical decision-making. However, given the observational design and absence of a comparator arm, conclusions regarding superiority over conventional TURBT cannot be drawn from the present study.

**Safety Profile**

Perioperative outcomes remained acceptable throughout implementation.

No clinically significant obturator reflex or bladder perforation was observed in this series.

Potential safety-related advantages include:

- Reduced occurrence of obturator reflex due to absence of electrical current.
- Controlled tissue interaction with limited penetration depth, potentially lowering perforation risk[8].
- Effective hemostasis facilitating intraoperative bleeding control.
- Predictable cutting and coagulation characteristics supporting controlled dissection.

However, these findings should be interpreted cautiously and not considered evidence of complete elimination of these complications.

**Comparison With Existing Literature**

Our findings are generally consistent with published literature describing favorable perioperative and pathological outcomes associated with laser-assisted en bloc resection techniques for bladder tumors. Previous systematic reviews and meta-analyses have reported improved specimen integrity, higher detrusor muscle detection rates, and acceptable perioperative safety profiles compared with conventional TURBT[9,10].

In the present study, progressive improvement in pathological quality indicators was observed during implementation, including increased detrusor muscle detection and reduced thermal artefact. Detrusor muscle detection reached 95% during later implementation phases, which is comparable to rates reported in experienced ERBT series[11,12].

However, direct comparison with conventional TURBT should be interpreted cautiously, as the present study was observational and did not include a contemporaneous comparator group. Similarly, conclusions regarding oncological outcomes cannot be drawn because long-term follow-up was outside the scope of the present analysis.

Overall, the findings should be interpreted as reflecting early implementation experience and procedural adaptation rather than comparative effectiveness.

**Clinical Implications**

The findings of this implementation study suggest several potential practical implications for centers considering adoption of thulium laser en bloc resection:

1. Pathological assessment: Improved specimen quality and higher detrusor muscle detection may support pathological evaluation and staging accuracy.
2. Procedural efficiency: Progressive improvement in operative efficiency and short perioperative recovery parameters may facilitate integration into routine clinical workflow.
3. Implementation considerations: Standardized operative protocols, appropriate case selection, and multidisciplinary coordination may support successful introduction of this technology.
4. Future evaluation: Additional studies incorporating long-term oncological outcomes, cost analyses, and multicenter experience are required to define the broader clinical impact of implementation.

**STUDY LIMITATIONS**

Several limitations should be acknowledged.

First, this was a single-center observational implementation study and all procedures were performed by a single surgeon, which may limit generalizability.

Second, patient-level and tumor-level outcomes were both evaluated and may introduce unit-of-analysis bias.

Third, although pathologists were blinded to chronological sequence, interobserver variability cannot be completely excluded.

Fourth, long-term oncological outcomes including recurrence and progression were not evaluated.

Fifth, although patients with T1 disease underwent repeat TURBT according to institutional practice, re-TURBT outcomes were not analyzed in the present study.

Finally, absence of a contemporaneous conventional TURBT control group limits causal inference.

# CONCLUSION

Implementation of thulium laser en bloc resection at a tertiary care center demonstrated feasibility and acceptable perioperative outcomes during early adoption.

Progressive improvement in operative efficiency, specimen quality, and procedural consistency was observed across chronological case groups.

These findings support the possibility of successful implementation using structured protocols, careful case selection, and multidisciplinary coordination.

Further studies with long-term oncological follow-up and comparative evaluation are required before broader conclusions regarding effectiveness can be made.

# Declarations

### Data Availability Statement

The data supporting the findings of this study are not publicly available due to privacy and confidentiality considerations. However, data may be made available from the corresponding author upon reasonable request.

### Ethics approval and consent to participate:

The study was approved by the **Institutional Ethics Committee** (Protocol No. AIIMS/IEC/24/100) and written informed consent was obtained from all participants.

### Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.


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### Clinical Trial No. : Not Applicable

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# Tables

**Table 1. Laser System Parameters of the Quanta Cyber TM Thulium:YAG Laser Used in This Study**

| Parameter | Specification |
|---|---|
| Type of laser | Thulium:YAG (Tm:YAG) laser |
| Wavelength | 2013 nm |
| Emission mode | Continuous-wave |
| Time on / time off | Continuous output (100% duty cycle) |
| Delivery system | 600-µm silica end-firing fiber |
| Power setting | 30 W |
| Energy distribution | Homogeneous, shallow penetration (~0.2 mm) |
| Spot diameter at focus | ~600 µm |
| Focus spot area | ~0.28 mm² |
| Spot diameter at tissue | 600–750 µm |
| Focus-to-tissue distance | 0–2 mm |
| Spot area at tissue | 0.28–0.44 mm² |
| Peak power | 30 W |
| Average power | 30 W |
| Peak power density (focus) | ~107 W/mm² |
| Peak power density (tissue) | ~68–107 W/mm² |
| Beam divergence | 8–12° |
| Water irrigation | Continuous saline irrigation |
| Air/aspiration airflow | Not applicable |

**Table 2. Patient Demographics**

| Characteristic | Laser en bloc resection (n=55), n (%) |
|---|---|
| **Age (years)** | |
| Mean ± SD | 60 ± 12 |
| Range | 38–85 |
| **Age groups** | |
| <65 years | 29 (52.7) |
| ≥65 years | 26 (47.3) |
| **Sex** | |
| Male | 47 (85.5) |
| Female | 8 (14.5) |
| **Comorbidities** | |
| Diabetes mellitus | 17 (30.9) |
| Hypertension | 17 (30.9) |
| Chronic kidney disease | 8 (14.5) |
| Coronary artery disease | 5 (9.1) |
| COPD | 30 (54.5) |
| No significant comorbidity | 12 (21.8) |
| **Smoking history** | |
| Yes | 46 (83.6) |
| No | 9 (16.3) |

**Table 3. Tumor Characteristics**

| Characteristic | Value (n=75 tumors, 55 patients) |
|---|---|
| **Tumor number per patient** | |
| Single tumor | 35 patients (63.6) |
| Multiple tumors (two) | 20 patients (36.4) |
| **Tumor size** | |
| ≤3 cm | 72/75 (96%) |
| >3 cm | 3/75 (4%) |
| **Tumor location** | |
| Posterior wall | 13 (17.3%) |
| Dome | 7 (9.3%) |
| Anterior wall | 3 (4%) |
| Right lateral wall | 14 (18.6%) |
| Left lateral wall | 13 (17.3%) |
| Right posterolateral wall | 15 (20%) |
| Left posterolateral wall | 11 (14.6%) |
| **Tumor type** | |
| Papillary | 69 (92%) |
| Non-papillary | 6 (8%) |

**Table 4. Operative Time Evolution**

| Case Group | Mean Operative Time per Case (min) ± SD | Mean Tumors per Case |
|---|---|---|
| 1–10 | 38.0 ± 3.5 | 1.3 |
| 11–20 | 30.5 ± 2.2 | 1.2 |
| 21–30 | 28.2 ± 1.5 | 1.3 |
| 31–55 | 27.8 ± 1.2 | 1.48 |