

# original article

## Impact of 3D high-definition laparoscopy on total laparoscopic hysterectomy: a body mass index-stratified retrospective analysis

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**BACKGROUND:** Three-dimensional (3D) high-definition (HD) laparoscopy is a promising tool in minimally invasive gynecologic surgery, offering enhanced depth perception and visualization. However, its role in total laparoscopic hysterectomy (TLH), particularly in patients with varying body mass index (BMI), remains underexplored.

**OBJECTIVE:** To evaluate the impact of 3D HD laparoscopy on surgical efficiency and patient outcomes in TLH, with a focus on BMI-related differences.

**DESIGN AND SETTINGS:** A single-center retrospective study

**PATIENTS AND METHODS:** Sixty patients who underwent TLH were included: n=30 used 3D HD laparoscopy (Aesculap 3D EinsteinVision) and n=30 matched controls used 2D laparoscopy. Matching criteria included uterine weight and prior surgical history. Patients were stratified according to BMI ( $\leq 24.9$ ,  $25-29.9$ ,  $\geq 30.0 \text{ kg/m}^2$ ).

**MAIN OUTCOME MEASURES:** Operative time, vault suturing time, blood loss, trocar site incisions, haemoglobin drop, and complication rates.

**SAMPLE SIZE:** 60 patients (30 in each group)

**RESULTS:** The 3D HD laparoscopy group demonstrated significant improvements across multiple outcomes. Trocar site incisions were significantly reduced in all BMI categories ( $P<.001$ ). Vault suturing time was shorter in the 3D HD laparoscopy group ( $P=.002$ ), and total operative time was reduced in overweight patients ( $P=.015$ ). Obese patients in the 3D group had lower haemoglobin drop ( $P=.01$ ) and reduced blood loss compared to 2D laparoscopy group ( $P=.017$ ).

**CONCLUSION:** 3D HD laparoscopy enhances surgical efficiency in TLH, especially in patients with higher BMI, by minimizing trocar site incisions, reducing vault suturing times, and improving hemostasis—highlighting its value in overcoming challenges of minimally invasive gynecologic surgery.

**LIMITATIONS:** The study's retrospective design and modest sample size limit generalizability.

**CONFLICT OF INTEREST:** None.

**KEYWORDS:** 3D HD Laparoscopy, Minimally Invasive Gynecology, Surgical Outcomes Optimization, Obesity in Laparoscopy

Total laparoscopic hysterectomy (TLH) has become the gold standard for benign gynecological conditions due to its minimal invasiveness, reduced recovery time, and improved cosmetic outcomes compared to traditional abdominal hysterectomy.<sup>1</sup> Despite these advantages, challenges persist, particularly in patients with higher body mass index (BMI), where increased adiposity can complicate visualization, surgical precision, and overall procedural efficiency.<sup>2</sup> To address these challenges, advancements such as three-dimensional (3D) high-definition (HD) laparoscopy offer enhanced depth perception and superior visualization compared to conventional two-dimensional (2D) systems. 3D HD laparoscopy may improve surgical outcomes by enabling more precise tissue handling, reducing intraoperative complications, and improving the surgeon's spatial orientation.<sup>3</sup> This technology could be particularly advantageous in patients with obesity or increased abdominal adiposity by overcoming the visual limitations of conventional 2D laparoscopy in accessing deep anatomical structures.<sup>4</sup>

Previous studies have shown that advanced laparoscopic technologies can improve surgical outcomes by reducing operative time, blood loss, and complication rates in patients with higher BMI.<sup>5</sup> However, the specific role of 3D HD laparoscopy on TLH, particularly regarding BMI as a potential modifier of its effectiveness, remains underexplored.

In addition to advancements in surgical equipment, the widespread adoption of laparoscopic procedures has been significantly facilitated by the evolution of online learning platforms and digital resources [Author: insert reference]. These platforms have democratized access to training and education, enabling surgeons worldwide to acquire and refine their skills in minimally invasive techniques. For instance, virtual reality (VR) simulators and interactive online modules have been shown to enhance the acquisition of laparoscopic skills, reduce learning curves, and improve confidence in performing complex procedures like TLH.<sup>6</sup> Furthermore, the integration of telementoring and remote proctoring through online platforms enabled experienced surgeons to provide real-time guidance to less-experienced colleagues, enhancing procedural safety and outcomes.<sup>7,8</sup> These advancements underscore the critical role of technology not only in enhancing surgical tools but also in fostering global dissemination and standardization of laparoscopic expertise.

This study aims to evaluate the impact of 3D HD laparoscopy (Aesculap 3D EinsteinVision) in TLH by examining its effects on surgical efficiency, complica-

tion rates, and patient outcomes across different BMI categories. By addressing this gap, we hope to provide insights into how 3D HD laparoscopy can optimize surgical outcomes, particularly in challenging patient populations such as those with higher BMI.

## PATIENTS AND METHODS

### Study design

This retrospective cohort study was conducted at a single institution, evaluating 60 patients who underwent total laparoscopic hysterectomy (TLH) from January 2024 to December 2024. Thirty patients were operated using 3D high-definition (HD) laparoscopy (Aesculap 3D EinsteinVision), while the remaining 30 patients underwent conventional two-dimensional (2D) laparoscopy. The study was approved by the Institutional Review Board (Approval no: IKD-25-234, January 2025).

### Data collection and analysis

Data were collected from electronic medical records, including patient demographics, surgical parameters, and postoperative outcomes. Key parameters included operative time, vault suturing time, blood loss, trocar site incisions, haemoglobin drop, and postoperative complications. Patients were grouped into BMI categories:  $\leq 24.9$ ,  $25\text{--}29.9$ , and  $\geq 30.0 \text{ kg/m}^2$ . The two groups were matched based on uterine weight and prior surgical history to minimize confounding variables.

### Procedures

All surgeries were performed by the same experienced surgeon using either 3D HD laparoscopy or conventional 2D laparoscopy. In both groups, TLH was performed following standard surgical protocols. The 3D HD system (Aesculap 3D EinsteinVision) provided enhanced visualization through improved depth perception, which may aid in spatial orientation during surgery. However, the clinical significance of this enhancement was evaluated as part of the study outcomes rather than assumed a priori. The 2D group relied on traditional laparoscopic technology, which has been widely used in clinical practice.

### Follow-up

All patients were followed up after 1 week, 1 month, and 3 months postoperatively. Follow-up assessments included monitoring for complications such as infection, bowel injury, or bleeding, as well as routine postoperative care, including clinical examination and haemoglobin levels.

### Statistics

Statistical analysis was done using SPSS (version 25). Prior to performing parametric tests, normality testing was conducted using the Shapiro-Wilk test for continuous variables. For normally distributed data, independent T-tests were used to compare means between groups. For non-normally distributed data, the Mann-Whitney U test was applied. Categorical variables were compared using either Chi-square or Fisher's exact tests, as appropriate. Subgroup analysis was performed based on BMI categories to assess the differential impact of 3D laparoscopy across various body types. A  $P$  value  $<.05$  was considered statistically significant.

## RESULTS

### Patient demographics and baseline characteristics

The baseline characteristics of the patients in both groups were comparable. The mean age, BMI, and uterine weight were not significantly different between groups (**Table 1**). The patients were stratified into BMI categories of  $\leq 24.9$ ,  $25\text{--}29.9$ , and  $\geq 30.0 \text{ kg/m}^2$ , ensuring a balanced representation of normal-weight, overweight, and obese individuals in both the 3D and 2D laparoscopy groups.

### Surgical outcomes

#### Operative time

The total operative time was significantly shorter in the 3D HD group than the 2D group, with a mean operative time of  $95.3\pm14.2$  minutes vs  $110.2\pm16.4$  minutes, respectively ( $P=.008$ ). This significant reduction was particularly notable in overweight patients, where the 3D group demonstrated a mean reduction of 18.4 minutes in total operative time ( $P=.015$ ).

#### Vault suturing time

Vault suturing time was also significantly shorter in the 3D HD group than the 2D group, with an average suture time of  $12.7\pm3.1$  minutes vs  $17.9\pm4.2$  minutes, respectively ( $P=.002$ ).

#### Blood loss and hemoglobin drop

The 3D HD group exhibited significantly lesser blood loss, with an average of  $58.4\pm25.1$  ml compared to  $82.3\pm32.5$  ml in the 2D group ( $P=.017$ ). Additionally, the mean hemoglobin drop in the 3D group was significantly lower than the 2D group [ $1.2\pm0.7 \text{ g/dL}$  vs  $1.8\pm0.9 \text{ g/dL}$  ( $P=.01$ )].

### Trocar site incisions

In the 3D group, the mean number of trocar sites was  $3.1\pm0.5$ , compared to  $3.7\pm0.6$  in the 2D group ( $P<.001$ ). Both groups utilized one optical trocar for the camera; however, the 3D group required fewer additional trocars due to improved visualization and spatial awareness (**Table 2**).

### Postoperative complications

#### Overall complications

The overall postoperative complication rate (3, 10%) was lower in the 3D HD group (10%) compared to the 2D group (5, 17%), though this difference did not reach statistical significance ( $P=.31$ ). The most common complications in both groups were urinary retention (1, 3% in 3D and 2, 7% in 2D) and vaginal cuff dehiscence (0 in 3D vs 2, 3% in 2D). No major complications such as visceral injury were observed in either group (**Table 3**).

## DISCUSSION

TLH has become the standard of care for benign gynecological conditions due to its minimal invasiveness, reduced recovery time, and superior cosmetic outcomes compared to traditional abdominal hysterectomy.<sup>1</sup> However, challenges persist, particularly in patients with higher BMI, where increased adiposity complicates visualization, surgical precision, and procedural efficiency. In this context, the integration of 3D HD laparoscopy represents a promising advancement by offering enhanced depth perception and superior visualization.<sup>2</sup> Our study aimed to evaluate the role of 3D HD laparoscopy in TLH, with a specific focus on its impact on surgical efficiency and patient outcomes across BMI categories. The findings demonstrated significant improvements in various surgical parameters in favor of the 3D HD group compared to 2D laparoscopy, particularly in patients with higher BMI. These improvements included significantly fewer trocar site incisions, shorter vault suturing times, reduced blood loss, and lower hemoglobin drop.

The results align with findings from recent studies that have highlighted the advantages of 3D laparoscopy, particularly in obese patients, where conventional 2D systems often struggle to provide adequate visualization due to increased abdominal fat. For example, a study demonstrated that 3D laparoscopy significantly improved surgical outcomes in minimally invasive gynecological procedures, particularly in reducing operative time and improving hemostasis in obese patients.<sup>9</sup>

**Table 1.** Baseline characteristics of the 3D and 2D groups.

Characteristics	3D HD Laparoscopy (n=30)	2D Laparoscopy (n=30)	P value
Mean age (years)	46.2 (5.3)	46.1 (4.9)	.85
Mean body mass index (kg/ m <sup>2</sup> )	27.1 (4.2)	27 (3.9)	.92
Uterine weight (g)	240 (35)	245 (30)	.63

Data presented as mean (SD).

**Table 2.** Surgical outcomes between 3D and 2D groups.

Outcome	3D HD Laparoscopy (n=30)	2D Laparoscopy (n=30)	P value
Total operative time (minutes)	95.3 (14.2)	110.2 (16.4)	.008
Vault suturing time (minutes)	12.7 (3.1)	17.9 (4.2)	.002
Blood loss (ml)	58.4 (25.1)	82.3 (32.5)	.017
Hemoglobin drop (g/dL)	1.2 (0.7)	1.8 (0.9)	.01
Trocar site incisions (n)	3.1 (0.5)	3.7 (0.6)	<.001

Data presented as mean (SD); significant at P<.05.

**Table 3.** Postoperative complications.

Complications	3D HD Laparoscopy (n=30)	2D Laparoscopy (n=30)	P value
Urinary retention	1 (3)	2 (7)	.49
Vaginal cuff dehiscence	0	1 (3)	.31
Overall complication rate	3 (10)	5 (17)	.31

Data presented as n (%).

Similarly, one study reported that 3D laparoscopy enhanced depth perception and spatial awareness, leading to better surgical precision and reduced complications in complex surgeries such as TLH.<sup>10</sup> Another study found that 3D laparoscopy reduced blood loss and improved suturing accuracy, particularly in obese patients undergoing TLH.<sup>11</sup> These studies collectively underscore the transformative potential of 3D HD laparoscopy in overcoming the challenges associated with higher BMI during laparoscopic procedures.

#### Trocar site incisions

Our study found that 3D HD laparoscopy reduced the number of trocar site incisions across all BMI categories, with a significant reduction observed in both overweight and obese patients. This aligns with prior research suggesting that 3D HD laparoscopy improves depth perception, enabling more accurate trocar place-

ment and minimizing unnecessary incisions.<sup>5</sup> A study similarly reported that 3D laparoscopy minimized the need for additional trocar placements by enhancing the surgeon's ability to navigate the surgical field effectively.<sup>11</sup> This reduction in trocar sites is clinically significant, as it may contribute to reduced postoperative pain and faster recovery, consistent with other studies investigating minimally invasive surgery techniques.<sup>2</sup>

#### Operative time

The total operative time was significantly shorter in the 3D HD laparoscopy group, especially in patients who were overweight. This is consistent with findings from a meta-analysis which showed that 3D laparoscopy reduced operative times in minimally invasive gynecological procedures, particularly in patients with higher BMI.<sup>9</sup> A reduction in operative time not only minimizes the duration of anesthesia exposure but also improves

surgical efficiency, potentially reducing the risk of complications associated with prolonged surgeries.<sup>3</sup> Our results are further supported by a recent study demonstrating that 3D laparoscopy shortened operative times in TLH by providing superior visualization and improving the surgeon's ability to navigate anatomical structures in challenging cases.<sup>10</sup>

#### **Vault suturing time**

The shorter vault suturing time observed in the 3D HD laparoscopy group is another key finding of this study. Previous research has demonstrated that enhanced visualization with 3D laparoscopy enables more precise handling of tissues, leading to faster and more efficient suturing.<sup>5</sup> A study highlighted that 3D laparoscopy improved suturing accuracy, particularly in obese patients, where conventional 2D systems often struggle to visualize deep structures.<sup>11</sup> The reduction in suturing time is crucial, as it may reduce the risk of intraoperative complications such as bleeding and injury to surrounding tissues.<sup>6</sup> Moreover, the ability to accurately visualize and manipulate tissues during suturing is particularly beneficial in patients with obesity, where the increased abdominal fat may obscure structures and complicate the procedure.<sup>5</sup>

#### **Blood loss and hemoglobin drop**

A significant reduction in blood loss and hemoglobin drop was observed in the 3D HD laparoscopy group, particularly among obese patients. Recent studies have shown that 3D laparoscopy improves hemostasis by providing better visualization of blood vessels and surrounding tissues.<sup>7</sup> One meta-analysis emphasized that 3D HD laparoscopy significantly reduced blood loss in minimally invasive gynecological procedures, particularly in obese patients.<sup>9</sup> In contrast, conventional 2D laparoscopy may struggle to identify bleeding points accurately due to limited depth perception, whereas 3D HD laparoscopy enhances the surgeon's ability to visualize and control bleeding effectively. This advantage is particularly important in TLH, where hemostasis is critical, and excessive blood loss can lead to complications such as transfusion requirements and delayed recovery.<sup>7</sup>

#### **Postoperative complications**

While the overall complication rate was lower in the 3D HD laparoscopy group (10% vs. 16.7%), the difference was not significant. However, the incidence of urinary retention and vaginal cuff dehiscence was lower in the 3D group, suggesting a potential benefit of 3D HD laparoscopy in reducing certain postoperative complications. These findings echo a similar study which re-

ported lower complication rates in 3D HD laparoscopy than 2D, particularly in complex surgeries involving patients with higher BMI.<sup>8,10</sup> However, further studies with larger sample sizes are needed to fully assess the impact of 3D laparoscopy on long-term postoperative outcomes.

#### **Integration of Enhanced Recovery After Surgery (ERAS) protocols**

Enhanced Recovery after Surgery (ERAS) protocols have gained widespread recognition for their ability to optimize perioperative care and accelerate recovery in gynecological surgery.<sup>12</sup> A recent review highlighted the role of ERAS protocols in reducing hospital length of stay, postoperative pain, and complications while improving patient satisfaction.<sup>12</sup> In the context of TLH, the integration of 3D HD laparoscopy with ERAS principles could further enhance recovery outcomes. For example, the reduced operative time and improved hemostasis observed in the 3D HD group align with ERAS goals of minimizing surgical stress and optimizing recovery. Future studies should explore the synergistic effects of combining 3D HD laparoscopy with ERAS protocols to maximize patient benefits.

#### **Advantages and drawbacks of surgical approaches**

Laparoscopic surgery offers distinct benefits over open surgery, including reduced invasiveness, shorter recovery times, and better cosmetic outcomes. However, laparoscopy is not without its challenges, particularly in obese patients, where limited visualization and restricted maneuverability can increase the risk of complications. The trade-offs between laparoscopic and robotic-assisted approaches emphasized that while laparoscopy is cost-effective and widely accessible, robotic systems offer enhanced dexterity and visualization at a higher cost.<sup>13</sup> The emergence of 3D HD laparoscopy bridges this gap by providing superior visualization without the added expense of robotic systems, making it a viable option for centers with limited resources. Our study supports this by demonstrating that 3D laparoscopy improves surgical efficiency and outcomes, particularly in obese patients, thereby addressing many of the limitations of conventional 2D laparoscopy.

#### **LIMITATIONS**

This study has several limitations. As a retrospective cohort study, it is prone to selection bias, and the small sample size may limit the generalizability of our findings. Furthermore, surgeon experience with

3D laparoscopy could influence the results, as proficiency in this advanced technology may improve with increased usage. Therefore, prospective, multicenter, randomized controlled trials with larger sample sizes are necessary to validate the benefits of 3D laparoscopy in TLH. Additionally, future studies should explore long-term outcomes, including patient satisfaction, recovery time, and quality of life, to provide a comprehensive assessment of the impact of 3D laparoscopy on TLH outcomes.

### CONCLUSION

In conclusion, the integration of 3D HD laparoscopy

into TLH significantly improves surgical efficiency and patient outcomes, particularly in patients with higher BMI. By enhancing visualization, reducing trocar site incisions, shortening vault suturing times, and improving hemostasis, 3D laparoscopy overcomes several challenges associated with laparoscopic surgery in obese patients. These findings suggest that 3D HD laparoscopy could play a key role in improving the success of minimally invasive gynecological procedures, particularly for patients with high BMI. Future prospective studies are warranted to further validate these results and explore the long-term benefits of 3D laparoscopy in TLH.

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