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Review Article

Supraglottic Devices in Laparoscopic Surgery - A Review of Literature

Shalini Subramanian* and Divya Sethi

ESI PGIMSR and Associated Hospital, Basaidarapur, New Delhi, India

Abstract

Supraglottic Airway Devices (SAD) offer several advantages over endotracheal intubation including reduced hemodynamic response, decreased anaesthetic requirement for airway tolerance and lesser pharyngolaryngeal morbidity. Second generation SADs incorporate a drain tube in their construction to separate the respiratory and alimentary tract. They offer better oropharyngeal seal and improved protection against regurgitation and aspiration. Laparoscopic Surgery (LS) involves generation of pneumoperitoneum and positioning with head up or head down tilt with resultant cardiovascular and respiratory effects. LS offer the ultimate test for the efficacy of SAD use in the face of changes in intra-abdominal pressure and thoracic compliance. Careful choice of the anesthetic technique and patient selection has allowed effective use of SAD in LS. This review seeks to explore the use of second generation SAD with particular reference to PLMA, SLMA and i-gel in laparoscopic surgery.

Introduction

Supraglottic Airway Devices (SADs) made their entry into the anesthesiologist's armamentarium in 1983 with the introduction of the Classic Laryngeal Mask Airway (CLMA) [1]. Their use in Laparoscopic Surgery (LS) has been described a non conventional use but feasible [2]. The second generation SADs with an esophageal vent has been developed to improve airway seal and decrease the risk of aspiration [3]. Lu et al., have shown the better suitability of SAD with a drain tube for securing the airway in laparoscopic procedures [4]. This review seeks to detail the literature on use of second generation SADs in laparoscopic surgery with reference to Proseal Laryngeal Mask Airway (PLMA), LMA- Supreme (SLMA) and Inter-surgical i-gel (i-gel).

We searched the database of MEDLINE, Scopus, Cochrane for English language studies between 1997 and 2014 using the keywords laryngeal mask airway, LMA, ProSeal LMA, PLMA, Supreme LMA, SLMA, i-gel, laparoscopic. The year 1997 was chosen as the starting point as ProSeal LMA came into clinical use soon after in 2000.

***Corresponding author:** Shalini Subramanian, ESI PGIMSR and Associated Hospital, Basaidarapur, New Delhi - 110015, India, Tel: +91 7406610222; E-mail: drshalinisubramanian@gmail.com

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Device Description

	PLMA (Figure 1a)	SLMA (Figure 1b)	I-gel (Figure 1c)
Year of introduction	2000	2007	2007
Material	Medical grade silicone, reusable (autoclavable)	PVC, single use	Gel like thermoplastic elastomer (Styrene ethylene butadiene styrene), single use
Sizes available	1,1.5,2,2.5,3,4,5	1,1.5,2,2.5,3,4,5	1,1.5,2,2.5,3,4,5
Description	Reinforced airway tube, bowl and inflatable double cuff (single in size<3), silicone drain tube, bite block and pocket for introducer	Preformed curved shaft consists of a double lumen, i.e., a central drain tube encased within a flattened oval-shaped airway lumen, inflatable single cuff, a built-in bite block and moulded fins at the laryngeal outlet to prevent epiglottic obstruction	Cuffless device anatomically designed to conform to the shape of hypo-pharynx with drain tube and integrated bite block
Drain tube characteristics	Runs through device from tip to proximal end by the side of the airway tube	Runs through the middle of the semi-rigid airway tube dividing it into two halves	Narrower bore drain tube with truncated tip that penetrates lesser into the esophageal inlet in comparison with PLMA or SLMA
Size of gastric tube	PLMA 3 : 16 Fr PLMA 4 : 16Fr PLMA 5 : 18Fr	SLMA 3 : 14 Fr SLMA 4 : 14 Fr SLMA 5 : 14 Fr	i-gel 3 : 12 i-gel 4 : 12 i-gel 5 : 14
First time insertion success rate	76-100% (87.3%)	86-100% (~90%)	>85%
OLP (cm H_2O)	27-31	26-30	26-30

Table 1 and Figure 1(a-c): Gives a description of the three SADs and technical details [5-10].

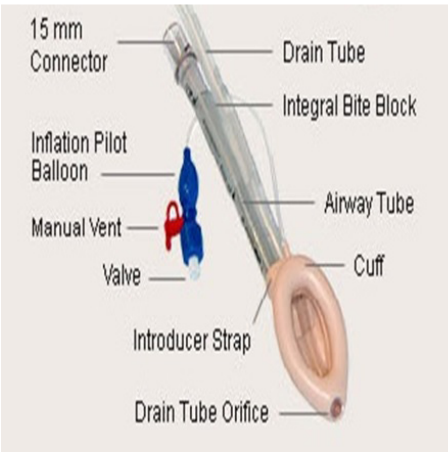

Figure 1a: PLMA.

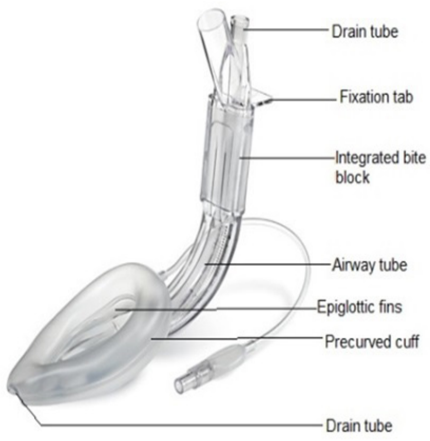

Figure 1b: SLMA.

Figure 1c: i-gel.

Ease of insertion

The SAD may be inserted using the standard (finger guided), introducer guided or gastric tube guided techniques. The bougie guided technique of PLMA had the highest success rate of 100% in comparison with the other methods of PLMA insertion [11]. All the three SADs devices had a 100% success rate of insertion in three attempts [8]. The insertion characteristics depend on the cuff size and design, method of insertion and the chosen end point for insertion time (insertion of device, connection to circuit, effective ventilation or satisfactory capnograph).

Oropharyngeal Leak Pressure (OLP)

The OLP depends on the method used to measure it. However all the 4 methods namely, detection of leak by auditory, auscultatory or capnographic method and manometric stabilisation have been shown to correlate [12]. The OLP in all the three devices PLMA, SLMA and i-gel are similar and in the range 25-30 cm H_2O with a cuff inflation pressure of 60 cm H_2O [8].

Drain tube

The second generation SADs has a drain tube which separates the alimentary and respiratory tracts. The diameter and position of this drain tube influences the ease of insertion of gastric tube. The PLMA and SLMA have a wider bore drain tube that forms a better esophageal seal; thus these devices should theoretically offer greater protection against aspiration than i-gel. The i-gel has a narrower drain tube though the manufacturer claims it offers enough esophageal seal. The esophagus forms a continuous tract with this drain tube. The ease of insertion of gastric tube was easier in SLMA as well as i-gel than in PLMA though the success of insertion was similar [13,14].

Pathophysiology of pneumoperitoneum and anesthetic concerns with use of SAD

Laparoscopic surgery requires creation of pneumoperitoneum and appropriate positioning to facilitate intra-abdominal visualization and surgical access. Several studies have established the safety of LMA in patients with normal respiratory compliance and airway pressure (Paw < 20 cm H_2O) [15]. Both these variables are affected in LS. The cardiovascular effects are more pronounced in the reverse Trendlenberg position while the respiratory embarrassment is more in the Trendlenberg (head down) position. There is a 30-50% decrease in thoraco-pulmonary compliance, increase in Paw and Pmean, decrease in FRC, V-Q mismatch and intra-operative basal atelectasis due to elevation of the diaphragm [16]. Maintenance of Intra-abdominal Pressure (IAP) <15 mm Hg and change in position between 15-20 has only minimal effects on non-obese and those without cardiac problems [17].

The level of airway protection afforded by the SAD is the interplay of several factors. Studies show decreased LES tone with the use of supraglottic airway device but no effect on the pharyngo-esophageal reflux [18,19]. The increase in IAP during LS may cause reflux of gastric contents with the risk of regurgitation or pulmonary aspiration [20]. However, it has been also revealed that the increase in IAP may induce an adaptive response in the LES that allows maintenance of pressure gradient across the gastro esophageal junction and may actually reduce the risk of regurgitation [21]. Further the head down position used in pelvic laparoscopy may be protective in preventing regurgitated fluid from entering the airway [16].

Evans et al., demonstrated the effective isolation of the respiratory and gastrointestinal tracts by the PLMA in paralyzed and non paralyzed patients [22]. Cadaver models have shown that Proseal LMA protects against regurgitation and aspiration by effective separation of the pharynx and larynx [23]. Bernandini et al., retrospectively analyzed the risk of pulmonary aspiration in 65712 procedures under general anaesthesia with positive pressure ventilation [24]. This included 35,360 surgeries under LMA, 2.4% of these being laparoscopic. There were three cases of pulmonary aspiration in the LMA group, none of them underwent LS. The major risk factor for aspiration was unplanned surgery. The low incidence of aspiration in the LMA group (1 in 11877) may be attributed to fewer LMA usages in emergency surgery. However, to reveal a true difference in aspiration risk between LMA and ETT, the number of patients needed to be studied is much larger (approximately fifty times greater). There have been case reports on the accidental aspiration of esophageal contents during the use of PLMA as well as i-gel [25,26]. In these cases, aspiration may have occurred due to mal positioning, stomach inflation due to air leak, unfamiliarity with the device or inappropriate patient selection.

SAD in laparoscopic cholecystectomy

Laparoscopic cholecystectomy is often conducted as day surgery [27]. The surgery involves creation of pneumoperitoneum and a

Study	Participants	Intervention(s)	Outcome(s)	OLP (cm H_2O)	Paw (after pneumoperitoneum) (cm H_2O)	Remarks
Maltby et al., [31]	109 ASA I-III adults including obese patients (BMI>30 kg/m2) undergoing LC	Prospective randomised trial to compare PLMA with ETT	Ventilation parameters, gastric distension, respiratory events at extubation		PLMA : 25 ETT : 25	PLMA and ETT equally effective in non obese. 4 obese patients crossed over to ETT.
Gulec et al., [33]	63 ASA I-II non obese patients, aged between 20-70 years scheduled for LC	Prospective randomized trial to compare PLMA and ETT	Hemodynamic and respiratory parameters, plasma adrenalin, noradrenalin, dopamine and cortisol levels			PLMA produces less metabolic stress, cortisol levels higher in ETT than PLMA
Lu et al., [4]	80 anaesthetized, paralyzed patients (ASA 1-2, aged 18-80 yr) undergoing LC	Prospective randomized trial to compare PLMA with CLMA	Ease of insertion, OLP, peak airway pressure, oxygenation and ventilation, adverse events	PLMA : 29 CLMA :19	PLMA : 24 CLMA : 22	Use of CLMA for laparoscopic cholecystectomy not recommemded
Hosten et al., [13]	60 non-obese adult patients undergoing LC	Prospective randomized trial to compare SLMA with PLMA	OLP, insertion success rates, insertion times, degree of gastric distension, intra- and post-operative adverse events, and hemodynamic and respiratory response	PLMA : 27 SLMA : 27.8		Both are effective. Shorter device and drain tube insertion time with SLMA
Belena et al., [34]	120 non obese ASA1-3 patients age>18 years undergoing LC	Prospective, single-blind, randomised, controlled study to compare SLMA with PLMA	OLP, time and number of attempts for insertion, ease of drain tube insertion, adequacy of ventilation and the incidence of complication	PLMA : 30.7 SLMA : 26.8		SLMA higher success first attempt insertion rate, PLMA higher OLP and tidal volume achieved
Natalini et al., [32]	60 adult ASA physical status I, II, and III patients undergoing various laparoscopic surgery	Prospective, controlled, randomized, non-blinded clinical study to compare PLMA with cLMA	Heart rate, arterial pressure, inspiratory and expiratory V(T), airway pressure, $ETCO_2$ and SpO_2	PLMA : 23.5 CLMA : 22.9		PLMA and the LMA show similar airtight efficiency
Sharma et al., [35]	60 ASA I-II adult non obese patients scheduled for LC	Prospective randomized comparative study to compare PLMA and i-gel	OLP, respiratory mechanics	PLMA : 38.9 I-GEL : 35.6		PLMA better seal, ventilation of both comparable, malrotation greater with i-gel
Cha et al., [36]	124 anesthetized, paralyzed patients ASA 1 to 2; aged, 18 to 80 years undergoing LC	Prospective randomized trial to compare SLIPA with PLMA	Gastric distension, fibre-optic view of glottis opening, sore throat			SLIPA is as efficacious as PLMA
Chung et al., [37]	120 ASA physical status I-II patients, aged 18-65 yrs scheduled for LC	Prospective randomized non blinded trial to compare PLMA with Cobra perilaryngeal airway	Insertion characteristics, airway adequacies, ventilation efficacies, degrees of gastric distension, and postoperative adverse events	Cobra PLA : 28.3 PLMA : 29.4	Cobra PLA : 22.4 PLMA : 21.6	Both are comparable
Sharma et al., [38]	100 patients of physical status ASA I - III, aged 18-85 years of either sex, scheduled for various elective laparoscopic procedures	Prospective observational study to evaluate the PLMA as a ventilatory device	haemodynamic responses to insertion, ventilatory parameters, ease of gastric tube placement, gastric insufflation and postoperative complication	28.04	24.74	PLMA is a safe airway device Removal of gastric fluid is necessary
Maharjan et al., [39]	60 patients who underwent LC	Prospective randomized study to compare the laryngeal seal of i-gel vs ETT	Airway pressure, $ETCO_2$, SpO_2 Inhaled and exhaled tidal volume, minute volume, leak volume and leak fraction		I-GEL : 20.21 ETT : 20.55	i-gel suitable alternative to ett
Saraswat et al., [40]	60 non-obese ASA1-2 patients undergoing various laparoscopic surgery	Prospective randomized study to compare the efficacy of PLMA and ETT	Attempts and time taken for insertion, haemodynamic changes, oxygenation, ventilation and intraoperative and postoperative laryngopharyngeal morbidity	PLMA : 35		PLMA proved to be a suitable and safe alternative to ETT
Badheka et al., [41]	60 ASA physical status I and II non-obese adult patients undergoing various elective laparoscopic surgeries	Prospective randomized study to compare i-gel as an alternative to endotracheal tube	Ease, attempts and time for insertion, haemodynamic and ventilatory parameters, gastric tube insertion, and perioperative complication			i-gel requires less time for insertion with minimal hemodynamic changes when compared to ETT.
Esa et al., [42]	54 ASA1-2 non obese patients undergoing various laparoscopic surgeries	prospective randomized study comparing Laryngeal Tube Suction II™ (LTS II™) with PLMA	ease of insertion, haemodynamic changes, quality of airway seal, oxygenation and ventilation parameters and complication	LTSII : 33.6 PLMA : 35.7	LTSII : 20.6 PLMA : 22	clinical performance of the LTS II™ and the PLMA™ was comparable

Kang et al., [43]	98 adult patients undergoing various laparoscopic procedures	Prospective randomised study, comparing efficacy and adverse events among patients with low (limiting 25 cm H_2O, L group) and high (at 60 cm H_2O, H group) LMA cuff pressure groups with SLMA	Postoperative pharyngolaryngeal adverse events, safety and efficacy of ventilating with low cuff pressure	L group : 27.2 H group : 31.1	L group : 17.0 H group : 18.4	Low SLMA cuff pressure allowed safe airway management with lower incidence of postoperative pharyngolaryngeal adverse events
Jain et al., [44]	10 non obese ASA 1-2 patients undergoing LC	Observational study in anaesthetized paralysed patients with PLMA as airway device	Pulse rate, systolic/diastolic/mean blood pressure, $EtCO_2$, SpO_2, ABG, and peak airway pressure		21.2	PLMA effective for ventilation in laparoscopic surgery provided precautions to prevent hypercarbia are taken
Kahla et al., [30]	80 ASA 1-2 patients undergoing various laparoscopic surgery	Prospective randomized trial to compare SLMA vs ETT	Ease of insertion, OLP, gastric insufflation, ventilator capability, hemodynamic response	SLMA : 27.5	SLMA : 22.7 ETT : 18.7	SLMA and ETT were comparable
Belena et al., [28]	100 ASA physical status 1, 2, and 3 adult patients undergoing LC	Prospective observational study to evaluate the SLMA	Ease of insertion of device and drain tube, OLP, postoperative sore throat, Stomach size	28.8	22.9	SLMA is effective ventilatory device for laparoscopic cholecystectomy
Aydogmus et al., [45]	60 ASA 1 patients undergoing various laparoscopic surgeries	Prospective observational study to examine SLMA as airway device	Hemodynamic response, $EtCO_2$, postoperative complications			SLMA suitable alternative to ETT in laparoscopic surgery
Sharma et al., [46]	1000 consecutive patients ASA 1-3, including 123 obese patients undergoing various elective laparoscopic surgeries	Descriptive study, non randomized with PLMA as airway device	Details of insertion, OLP, ventilatory performance and safety data	36	18	PLMA effective in LS
Abdellatif et al., [47]	120 ASA1-2 patients undergoing various laparoscopic surgeries	Randomised controlled trial comparing PLMA and SLIPA	Number of insertion attempts, insertion time, ease of insertion, and fiberoptic bronchoscopic view, lung mechanics, postoperative complications	PLMA : 28.2 SLIPA : 27.1	PLMA : 24.3 SLIPA : 25.4	Both provide effective ventilation. Greater incidence of sore throat with PLMA. Blood on device more with SLIPA.

Table 2: SAD use in laparoscopic cholecystectomy or various laparoscopic surgery.

reverse Trendlenberg position with lateral tilt. The Peak Airway Pressure (Paw) increases by 5-7 cm H_2O after carboperitoneum. The airway pressure after reverse Trendlenberg position did not differ significantly from that in the supine position [28].

Effective gastric decompression is desirable from the stage of trochar insertion till end of surgery to avoid injury to the stomach and interference with surgery. Gastric drainage is also required especially if an intra-operative cholangiogram is done as it usually increases the gastric output [29]. When the surgeon's assessment of gastric inflation after trochar insertion and at the end of surgery before removal of laparoscope was noted, it was comparable between PLMA, SLMA and endotracheal tube [13,28,30,31]. Maltby et al., found that this gastric inflation occurred even when the gastric tube was connected to a continuous suction throughout the procedure. This has been attributed to different angles of visualization rather than true distension. Kahla et al., inserted a gastric tube and removed it after suction while Hosten et al., connected the gastric tube to a collection bag. Belena et al., connected the gastric tube to a bag after initial suctioning for 10 second. In all these cases, the gastric inflation did not interfere with the surgery. The conventional and gold standard anesthesia technique for laparoscopic cholecystectomy is endotracheal intubation and controlled ventilation. However after extensive experience with gynaecologic laparoscopy and sterilization procedure, LMA has been attempted to be used, in non obese well fasted patients without GERD and having low risk of aspiration, for laparoscopic cholecystectomy. Lu et al., concluded that the CLMA is unsuitable for laparoscopic cholecystectomy [4]. The CLMA provided adequate ventilation before carboperitoneum but was associated with a high incidence of suboptimal and failed ventilation with abdominal insufflations to 15 mm Hg. The peak airway pressure after carboperitoneum was similar in both the groups (24 cm H_2O PLMA and 22 cm H_2O CLMA) but exceeded the OLP (19 cm H_2O) in CLMA group and hence provided ineffective ventilation. Natalini et al., found the PLMA and CLMA comparable during usage in various LS. However, the authors increased the cuff pressure >60 cm H_2O in several patients to facilitate ventilation through the SAD [32].

Table 2 gives the list of studies where a second generation has been used to secure the airway in Laparoscopic Cholecystectomy (LC) or various elective laparoscopic procedures.

The PLMA is the standard benchmark state of art second generation SAD with which any new SAD is compared [7]. Since its introduction in 2000, several studies have demonstrated the feasibility and efficiency of PLMA as an airway device in laparoscopic cholecystectomy. This includes eight prospective randomized trials comparing PLMA with other airway devices including ETT (two) [31,33], SLMA (two) [13, 34], cLMA (one) [4], i-gel (one) [35], SLIPA (one) [36] and Cobra peri-laryngeal airway (one) [37]. PLMA was found to be comparable with ETT in non-obese patients undergoing laparoscopic cholecystectomy [31,33]. In comparison with SLMA and i-gel, higher OLP was achieved with PLMA indicating better airway seal with this device. The SLMA was comparable with ETT in 80 patients undergoing laparoscopic surgery with no cases of failed ventilation or crossover from the SLMA group. The practicality of i-Gel use in laparoscopic cholecystectomy has been studied in two randomized trials. I-gel was found to be a workable alternative to ETT in LS in patients with normal airway pressures [39].

Single device studies have also been conducted to explore SAD use in various LS including laparoscopic cholecystectomy, appendectomy,

Study	Participants	Intervention(s)	Outcome(s)	OLP(cm H_2O)	Paw (after pneumoperitoneum) (cm H_2O)	Remarks
Maltby et al., [48]	209 women, ASA physical status I–III, including non-obese (BMI ≤ 30 kg/m2) or obese (BMI > 30 kg/m2)	Prospective randomized controlled trial to compare the CLMA in non-obese patients (BMI ≤30 kg/m2), PLMA in obese (BMI>30 kg/m2) and (ETT)	ventilation, change in stomach size and emergence outcomes	CLMA : 20 PLMA : 30	Pneumoperitoneum <15min Non-obese CLMA : 19 ETT : 21 Obese PLMA : 29 ETT : 28 Pneumoperitoneum >15min Non-obese CLMA : 22 ETT : 22 Obese PLMA : 33 ETT : 32	stomach size changes during surgery were not statistically significant Obese patients with Paw >OLP also had no gas leak during ventilation
Lim et al., [49]	180patients ASA grade 1-2, aged 18-80 y	Prospective randomized study to test the hypothesis that the PLMA is superior to ETT	Time to achieve an effective airway, ventilatory capability, peak airway pressure before and after pneumoperitoneum, duration of surgery and pneumoperitoneum and haemodynamic responses			PLMA AND ETT COMPARABLE FOR Gynaecologic Laparoscopy
Hohlrieder et al., [50]	100 non obese female patients (ASA I-II, 18-75 years)	Randomised double blind prospective study comparing ProSeal LMA with ETT	postoperative pain score, morphine requirement,PONV			pain and nausea less in PLMA than ETT group, no diff in vomiting
Griffiths et al., [51]	116 non-obese women	Observer-blinded randomised controlled trial comparing PLMA versus ETT	postoperative pain score, morphine consumption, emesis and adverse upper airway symptoms			PLMA did not decrease pain or PONV in comparison with ETT
Lee et al., [52]	70 patients	Prospective randomised controlled study comparing the SLMA with PLMA	OLP, ease of insertion, adequacy of ventilation and incidence of complications	PLMA : 31.7 SLMA : 27.9		SLMA had lower OLP and lower achieved Vte though not clinically significant, gastric tube insertion easier in SLMA
Jeon et al., [53]	30 non obese women ASA status 1 or 2, aged 18-65 years,	Prospective randomized study to compare PLMA and i-gel	Airway sealing pressure before and during pneumoperitoneum, insertion time, and gas exchange.	(after insertion) PLMA : 25.9 I-GEL : 24.3 (after pneumoperitoneum) PLMA : 28.3 I-GEL : 28.2	PLMA : 25 I-GEL : 24	I-GEL reliable alternative to PLMA
Roth et al., [54]	50 ASA 1-2patients	prospective, randomized study to compare PLMA and LTS.	Ease of insertion, quality of airway seal, risk of gastric insufflation and patient comfort	PLMA : 45.4 LTS : 45.6		Both devices provide a secure airway
Miller et al., [55]	150 non obese patients	Prospective randomized controlled trial to compare the efficacy of the ProSeal LMA and SLIPA™ with the standard Tracheal Tube (TT). The patients receiving a SAD were not paralysed	Ease of use, quality of seal, ventilation, systolic pressure, response to intubation, side effects and operating room time	PLMA : 31 SLIPA : 30	ETT : 20.2 PLMA : 21.3 SLIPA : 22.6	ProSeal LMA and SLIPA were easy to use without requiring muscle relaxants, and reduce operating roomtime compared to the TT technique in day case laparoscopies.
Abdi et al., [56]	138 elective pelvic laparoscopic ASA I-II female patients	Prospective randomized single-blind study to compare SLMA vs ETT	ventilation efficiency Anesthesia- and surgery-related time, Post-operative pain and pharyngolaryngeal morbidity			LMA Supreme and the ETT were equally effective airways for a routine gynecological laparoscopy
Teoh et al., [57]	100 ASA1-2 non obese female patients for laparoscopic surgery in the Trendelenburg position	Prospective randomized trial to compare the efficacy of i-gel with LMA Supreme	OLP, ease of insertion, haemodynamic response and time to insertion, efficacy in controlled positive pressure ventilation and complications of use	SLMA : 26.4 I-GEL : 25	SLMA : 23.8 I-GEL : 22.4	MORE TIME FOR DT INSERTION in i-gel, EASY DT INSERTION IN 100% SLMA VS 78% I-GEL Leak volume more in i-gel but no difference in OLP
Suhitharan et al., [58]	70 non obese anesthetized paralyzed patients	Prospective randomized controlled trial comparing the SLMA with i-gel	OLP, successful first attempt insertion rates, time and ease of the airway and gastric tube insertion, leak fraction and pharyngeal morbidity	SLMA : 25.9 i-gel : 24.4	SLMA : 23.3 i-gel : 22.8	Greater time to DT insertion and leak fraction in i-gel but not clinically significant. Both effective airway devices

Chattopadhyay et al., [59]	90 ASA 1-2 non-obese patients	Prospective randomized trial to compare SLMA vs i-gel	OLP, insertion characteristics, complications	SLMA : 24.4 i-gel : 23.6	SLMA : 23.4 i-gel : 22.5	Both are effective for ventilation. Gastric tube insertion easier in SLMA. Lesser sore throat with i-gel
Chen et al., [60]	120 adult, ASA physical status 1 and 2 women, aged 18 to 55 years.	Prospective, randomized study to test the hypothesis that muscle relaxant is not necessary in patients undergoing laparoscopic gynecological surgery with a PLMA	Peak airway inflation pressures, airway sealing pressure, minimum flow rate, and recovery time, Surgical conditions, sore throat	No muscle relaxant : 32 Muscle relaxant : 31		Shorter recovery time with no relaxant. Low flows possible with no relaxant
Belena et al., [61]	140 ASA 1-2 female patients	Prospective observational study evaluating use of SLMA	ease of insertion of the device and the drain tube, OLP, incidence of postoperative sore throat, and other adverse events	28.2	22	Included 5 obese patients with BMI > 35 kg/m2, SLMA safe and efficacious in standard cohort,
Mukkader et al., [62]	105 ASA 1-2 patients	Prospective randomized trial to compare PLMA, SLMA and i-gel	OLP, airway morbidity	PLMA : 23.9 SLMA : 24.9 i-gel : 21 OLP after 30 min PLMA : 25 SLMA : 25 i-gel : 28.3	PLMA : 21.4 SLMA : 21.3 i-gel : 21.37	initial OLP obtained by i-gel were lower than proseal and supreme, but increased over time. Ease of placement best for i-gel

Table 3: SAD use in gynaecological laparoscopic surgery.

inguinal herniorraphy, incisional hernia repair and gynaecological laparoscopy. The PLMA proved to be an effective ventilatory device in LS. There was only a single case of failed ventilation after carboperitoneum that was managed by changing to CLMA. There were three cases of regurgitation through the drain tube though no incidence of aspiration and gastric drainage was recommended by the authors. The authors stress on the experience of the user before habitual use in LS and a low threshold for switchover to an alternative device in the event of SAD malfunction [38].

Use of SAD in laparoscopic cholecystectomy also provides several other benefits. These include decreased hemodynamic stress, improved emergence characteristics like less cough, sore throat and dysphagia. Decreased PONV and post operative opiate consumption has also been reported but larger numbers have to be studied to prove this benefit [31,33,45].

SAD in gynaecological laparoscopy

Gynaecological laparoscopy was the earliest laparoscopic procedure to have an LMA inserted as the preferred airway device.

The usual gynaecological laparoscopic procedures are tubal ligation, diagnostic laparoscopy, hysterectomy, myomectomy and oophrectomy. It requires a Trendlenberg position of around 15° and lithotomy. All the three devices - PLMA, SLMA and i-gel have been used in gynaecological laparoscopy and the results are tabulated in table 3.

The effectiveness of SAD use in gynaecological surgery may be attributed to the short and elective nature of surgery, limitation of pneumoperitoneum and positioning to acceptable limits and the advantages offered by SAD in ambulatory surgery. Brimmacombe and Brain suggested "rule of 15" in guiding CLMA use in LS that is Trendlenberg tilt ≤15° Pabd ≤15 cm H_2O and peritoneal insufflation duration ≤15 minutes. While the first two hold true, it is now known that the suitability of the SAD in LS will be evident in the first 15 minutes and will continue to prove effective provided adequate anaesthetic depth and muscle relaxation is maintained and the SAD is not dislodged [48]. There are 9 randomized trials comparing PLMA with various other airway devices in laparoscopic gynaecological surgery. This includes comparison with ETT (4) and one each with SLMA, i-gel, LTS and Cobra PLA and one comparing PLMA, SLMA and i-gel [48-55,62]. The PLMA had equivalent functionality with ETT. The SLMA and i-gel were also comparable with PLMA. The differences in OLP and leak volume did not prove to be clinically relevant. Hohlrieder et al., found decreased analgesic requirement, pain scores and nausea with PLMA while Griffiths et al., found no difference in a similar group. Comparison of SLMA with i-gel has shown similar ventilator efficacy [50,51].

One point to note is that all patients were females and the results may not be extrapolated to males undergoing pelvic surgery in a similar position. Most of the studies have excluded obese women. Those which have included them found no difficulty in using SAD in obese patients [48,61]. The numbers however are small and no definitive conclusion may be made on their safety or efficacy in this cohort of patients.

SAD in paediatric laparoscopic surgery

The common laporoscopic surgical procedures in children include hernia repair, appendicectomy, cholecystectomy, orchiopexy and diagnostic laparoscopy. The cardiopulmonary effect of peritoneal insufflation in children is similar to that in adults but the effects are more pronounced at abdominal pressure of 12 mm Hg with significant decrease in cardiac output, increase in systemic vascular resistance compared to Pabd of 6 mm Hg [63].

Sinha and colleagues found the PLMA to have comparable ventilatory efficacy as ETT in short duration (<60 min) laparoscopic procedures in children aged 6 months to 8 years. The mean OLP was 29 cm H_2O and Paw after carboperitoneum was 23.79 cm H_2O [64]. In a descriptive study, Dave and colleagues successfully used PLMA for ventilating 30 children during LS lasting <60 min. In two patients, it required changeover to ETT due to suboptimal ventilation [65].

The literature and experience on second generation SAD use in paediatric laparoscopy is still insufficient to recommend its use. Hence its use, if at all should be restricted to brief laparoscopic procedures or examination of the abdomen with Pabd kept ≤10 mm Hg.

SAD in the obese patient

Alteration in respiratory mechanics, increased airway resistance and greater incidence of gastroesophageal reflux are the main concerns in choosing SAD as an airway device in obese patients. The advantages are decreased hemodynamic response during insertion and removal. They could also prove to be a valuable rescue device in difficult mask ventilation or intubation. A properly placed PLMA has been shown to provide good oxygenation, and reduce postoperative cough though inadequate information exists to comment on its ventilatory capabilities or vouch for its safety in obese patients undergoing routine or laparoscopic surgery [66].

Carron M et al., compared the hemodynamic and hormone stress response of PLMA and ETT in 70 morbidly obese pts (BMI > 30 kg/m^2) for laparoscopic banding surgery [67]. The study showed that there was significantly less hemodynamic and hormonal stress response with PLMA compared to ETT. The use of PLMA also showed reduction in the requirement for non-depolarizing muscle relaxant (ciastracurium) during surgery and oxygen de-saturation, pain and PONV scores in the postoperative recovery. In using an SAD for gastric banding, the use of a gastric tube rather than the usual balloon should be acceptable to the surgeon. Another point of concern is the use of PLMA for surgeries where postoperative gastric drainage is needed as the PLMA does not allow gastric drainage after its removal.

Ventilation with SAD in laparoscopic surgery

A ventilatory strategy that provides adequate oxygenation and ventilation in the face of increased airway pressure and resistance and decreased airway compliance is required during laparoscopic surgery. This is usually achieved with Volume Controlled Ventilation (VCV) with an increase in respiratory rate to increase the minute ventilation by around 20% after generation of the pneumoperitoneum. Pressure Controlled Ventilation (PCV) is associated with increased flow rates, faster achievement of tidal volume and lower peak airway pressure [53]. With an SAD *in situ*, it is necessary to ensure that the peak inspiratory pressure not exceed the oropharyngeal leak pressure. Jeon et al., found lower peak airway pressures and $PaCO_2$ with PCV in patients undergoing laparoscopic gynaecological procedures with PLMA [53].

Carron et al., were able to achieve adequate gas exchange with PCV and I:E ratio of 1:1 in obese patients undergoing gastric banding while ventilating through a PLMA [67]. No hemodynamic instability was noted in any of these studies during PCV.

Low fresh gas flow is associated with reduced anaesthetic gas exposure, improved costs, conservation of heat and humidity. The use of supraglottic airway device may be associated with greater gas leakage than the endotracheal tube. However, both low flow (Fresh gas flow <1 l/min) and minimal flow (FGF <0.5 l/min) have been used with controlled ventilation in a properly positioned LMA during laparoscopic surgery [48,60]. Several workers have reported the Leak Fraction (LF) using SAD in LS [32,39,57,58]. The LF is the difference between the inspired and expired tidal volume divided by the inspired tidal volume expressed as a percentage. A leak fraction of >15% is usually considered significant.

Limitations

There is a lot of heterogeneity with regard to SAD use in LS, in terms of experience of the user, type of device, method of insertion, nature of surgery, extent of pneumoperitoneum and positioning and mode of ventilation. Further, these studies are single blinded as it is not possible to blind the personnel using the device and recording the outcome. These issues need to be addressed in a meta-analysis.

Conclusion

Safety and efficacy are the critical factors that would define SAD use in LS. While efficacy has been demonstrated in several studies, protection against pulmonary aspiration is not guaranteed.

It must be understood that the success of SAD use in LS depends on the selection of the right cohort of patients and limiting pneumoperitoneum and positioning to acceptable limits. The key to successful use of SAD in laparoscopic surgery is insertion by an experienced user, ensuring correct position by clinical methods or fibre-optic bronchoscopy and the use of neuromuscular blockade and controlled ventilation. It is suggested that first time users gain reasonable expertise in short duration simple laparoscopic procedures like tubal ligation or diagnostic gynaecological laparoscopy before attempting their usage in other laparoscopic surgeries.

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