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Review

Endoscopic-assisted surgery in the management of breast cancer: 20 years review of trend, techniques and outcomes

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ABSTRACT

To review current literature on the outcomes, techniques and trend of endoscopic-assisted breast surgery (EABS) in the management of breast cancer over a 20 years period Materials and Methods: Literature search was performed using PubMed/Medline database from 1st January 1998 to 31st December 2018 using the terms “endoscopy”, “endoscopy-assisted”, “breast cancer”, “mastectomy” and “breast conserving surgery”. Additional studies were also identified by reviewing references of relevant articles. Only case series and cohort studies were included in this review. Oncological and surgical outcome measures as well as detailed technical aspects were discussed. Results: EABS was comparable in terms of oncological, surgical as well as aesthetic outcomes if compared to conventional techniques. Patient selection and important adjuncts are essential to ensure successful and safe conduct of EABS. Conclusions: Standardization of techniques, practice guidelines and objective outcome assessments methods might pave the way for better conduct of EABS and place EABS as one of the standards of care for breast cancer care.

Contents

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1. Introduction

Breast cancer treatment has taken a change in paradigm over the past few decades. In the 1940's, modified radical mastectomy was established as the new standard of care by David Patey for operable breast cancer, taking over Halsted radical mastectomy [1]. It was then the start of many landmark studies and advances in the surgical management of breast cancer. Breast conserving surgery (BCS), the next advancement in the surgical management of breast cancer, was introduced in 1969 through a randomized study comparing radical mastectomy and breast conserving surgery which was then termed 'quadrantectomy'. The long term survival of women with early breast cancer treated with breast conserving surgery and adjuvant radiotherapy has been proven to be comparable to women who underwent radical mastectomy [2,3].

In addition, with BCS gaining acceptance the surgical fraternity has witnessed another important field in the form of oncoplastic breast surgery, an approach for extending the possibilities of BCS, reducing both mastectomy and re-excision rates while avoiding disfiguring deformities [4–6]. Despite the offer of both breast conserving surgery as well as mastectomy, the demand for aesthetically pleasing yet oncologically safe surgical techniques has not abated and this had led to further modification such as nipple or skin sparing mastectomy with immediate implant or autologous tissue reconstruction [7–9].

The next kid on the block for surgical techniques would be that of endoscopic or laparoscopic-assisted approach, essentially technique that optimizes cosmetic outcome through small wounds hidden in inconspicuous areas. It is widely used in gastrointestinal, urologic and thoracic surgical fields [10–12]. Endoscopy-assisted breast surgery (EABS) which is performed through small axillary and/or periareolar incisions, was initially developed to facilitate breast augmentation [13,14], but is now increasingly used in excision of benign breast tumors [15–17] or breast cancer [18–20] as well as to assist in SLNB [21,22].

Since its introduction in the late 1990's, EABS has been shown to be an acceptable alternative technique for breast-conserving surgery in early breast cancer [22–24] as well as skin or nipple sparing mastectomy [25,26] followed by immediate autologous or implant reconstruction [27,28]. However, the use of EABS in the management of breast cancer has yet to become a mainstream treatment modality or the standard of care. The possible reasons for this could be due to the absence of randomized level I clinical evidence showing EABS to be equivalent to conventional techniques [29] or the lack of long term follow up data as most studies reporting on EABS had relatively short follow up duration [30].

In this article, we will review clinical studies over the past 20 years in order to ascertain the trend, techniques as well as outcome evaluations in endoscopic assisted breast surgery and discuss the current challenges or issues regarding EABS.

2. Materials and methods

Literature search was performed using PubMed/Medline database from 1st January 1998 to 31st December 2018 using the terms "endoscopy", "endoscopy-assisted", "breast cancer", "mastectomy" and "breast conserving surgery". Additional studies were also identified by reviewing references of relevant articles. Only case series and cohort studies were included in this review. Data obtained from each studies include study.

Details, tumour characteristics, operative techniques and outcomes from the surgical, oncological as well as aesthetic point of view. This article will review the studies in the following aspects and order:

- Outcome measures
  - I. Surgical outcomes;
  - II. Oncological outcomes;
  - III. Aesthetic estimation and patient satisfaction rating
- Technical Aspects
  - II. Selection criteria or indications;
  - III. Preoperative diagnostic imaging and marking;
  - IV. Operative method

3. Results

3.1. Overview of studies

From 1st January 1998 to 31st December 2018, there were altogether twenty-eight studies on endoscopic-assisted breast conserving and mastectomy (Tables 1 and 4). For endoscopic-assisted breast conserving surgery (E-BCS), 9 were case series whereas 6 cohort studies compared E-BCS to conventional breast conserving surgery (C-BCS) [19,21–23,31–41]. Endoscopic-assisted nipple sparing mastectomy (E-NSM) studies total up to 14, with 8 case series and 6 cohort studies (4 studies comparing E-NSM to.

Conventional nipple sparing mastectomy, C-NSM and 2 studies compared E-NSM to C- BCS) [18,25–28,35,42–49].

3.2. Outcome measures (Tables 2, 3, 5 and 6)

3.2.1. Surgical outcomes

3.2.1.1. Operative duration between E-BCS/E-NSM and conventional surgery. In terms of operative time for E-BCS studies, there were five cohort studies comparing E-BCS to conventional BCS (C-BCS)

Table 1
Studies on endoscopic assisted breast conserving surgery, patient and tumour characteristics.

No	Author	Year of publication	Journal	Number of patients	Operative method method	Average tumour size (cm, range or ± SD)	Clinical T stage, n (%)	Imaging tools for pre-operative marking
1	Tamaki	2001	Surg Laparosc Endosc Percutan Tech	6	E-BCS	1.6 (1.3–2.2)	T1: 6(100)	US
2	Owaki	2005	The Breast	6	E-BCS	Invasive lesion: 0.6; Non-invasive lesion: 0.27 (pathological diagnosis)	Tis: 1 (17); T1: 5 (83)	No data
3	Lee	2006	World J Surg	20	E-BCS	2.2 (0.2–4.0)	Tis: 4 (20); T1:8 (40); T2:8 (40)	MMG/US/MRI
4	Yamashita	2006	J Nippon Med Sch	82	E-BCS	1.8 (0.1–6.5)	Stage 0: 5 [6]; Stage I: 46 [56]; Stage IIA: 21 [26]; Stage IIB: 10 [12]	MRI
5	Yamashita	2008	Am J Surg	20	E-BCS	2.2	T1: 13 (65); T2:7 (35)	MRI
6	Nakajima	2009	Ann Surg	551	E-BCS	Tis: 2.5 ± 1.9; T1: 1.5 ± 0.5; T2: 3.6 ± 0.7	Tis: 47 [8.5]; T1: 190 [34.5]; T2: 314 [57.0]	US, MRI
7	Nakajima	2009	Ann Surg Oncol	244	E-BCS	1.6–3.1	Stage 1: 94 (38.5); Stage 2: 150 (61.5)	No data
8	Nakajima	2010	World J Surg	168	E-BCS	Tis: 3.5 ± 1.9; T1: 1.7 ± 0.3; T2: 3.6 ± 0.8	Tis: 24 (14.3); T1: 37 (22); T2: 107 (63.7)	US, MRI
9	Hong	2010	J Breast Cancer	22	E-BCS	2.23 ± 1.18	Tis: 1 (4.5); T1a: 1 (4.5); T1b: 1 (4.5); T1c: 9 (40.9); T2: 10 (45.5)	MMG/US/MRI
10	Park	2011	J Breast Cancer	40	E-BCS	1.5 ± 0.7	Tis: 1 [2.5]; T1: 30 [75.0]; T2: 9 [22.5]	MMG/US/MRI
				681	C-BCS	1.5 ± 0.7	Tis: 131 [19.3]; T1: 442 [65.0]; T2: 107 [15.7]	No data
11	Takemoto	2012	Surg Laparosc Endosc Percutan Tech	60	E-BCS	No data	Tis: 5 [9.8]; T1: 40 [78.4]; T2: 6 [11.8]	US etc
				51	C-BCS	No data	Tis: 5 [8.3]; T1: 45 [75.0]; T2: 10 [16.7]	US etc
12	Ozaki	2013	J Laparoendosc Adv Surg Tech	73	E-BCS	No data	Tis: 14 [19.2]; T1: 44 [60.3]; T2: 15 [20.5]	MMG, US, MRI, second-look US
				90	C-BCS	No data	Tis: 11 [12.2]; T1: 60 [66.7]; T2: 19 [21.1]	
13	Saimura	2013	Asian J Endosc Surg	61	E-BCS	1.4 (0.6–20)	Tis: 4 [6.6]; T1: 56 [91.8]; T2: 1 [1.6]	MMG, US, MRI
14	Takahashi	2014	Surg Today	100	E-BCS	1.6 ± 0.6	Stage 0: 4 (4); Stage 1: 61 (61); Stage 2A: 23 (23); Stage 2B: 12 (12)	No data
				150	C-BCS	2.1 ± 1.6	Stage 0: 12 (8); Stage 1: 74 (49.3); Stage 2A: 40 (26.7); Stage 2B: 24 (16)	No data
15	Lai	2016	PLOS One	46	E-BCS	2.2 ± 1.8 (0.1–8.5)	Stage 0: 66 (24.2) ; Stage 1: 88 (32.2); Stage 2: 117 (42.9); Stage 3: 2 (0.7) *This study combined E-BCS with E-NSM cases, hence distribution of stage according to type of surgery were not clearly illustrated	MMG, US

E-BCS: Endoscopic breast conserving surgery, C-BCS: Conventional breast conserving surgery, E-NSM: Endoscopic nipple sparing mastectomy, US: Ultrasound, MMG: Mammogram, MRI: Magnetic resonance imaging.

and the results were that E-BCS had an average operative duration that was either equal or 30–50 min longer than C-BCS [22,31,32,34,41]. In E-NSM studies, there were altogether six studies with four studies comparing E-NSM to conventional nipple sparing mastectomy (C-NSM) and another 2 studies comparing E-NSM to C-BSC. One study did not report data on operative time. The remaining five studies reported statistically significant longer operative time of 30–60 min for E-NSM if compared to C-NSM or C-BCS. Longer operative duration in E-BCS or E-NSM can be attributed to potential learning curve, different reconstruction method used as well as the need for equipment set up in E-BCS.

a) Learning curve analysis
   - One particular study [42] explored the learning curve of E-NSM and established an initial learning curve of about 30 cases before getting on the mature phase with statistically significant reduction in operative time.
b) Reconstruction methods
   - In one of the study comparing E-NSM to C-NSM [35], it was found that different types of reconstruction would have rendered the difference in operative duration statistically insignificant if compared to E- NSM or C-NSM with no reconstruction.

3.2.1.2. Intraoperative blood loss between E-BCS/E-NSM and conventional surgery. In the five E-BCS cohort studies, 3 studies reported no statistically difference in terms of intraoperative blood loss between E-BCS and C- BCS whereas one study reported statistically significant more intra-operative blood loss in E-BCS group [31]. One study did not report on intra-operative blood loss. In E-NSM studies, there were altogether six studies with four studies comparing E-NSM to conventional nipple sparing mastectomy (C-NSM) and another 2 studies comparing E-NSM to C-BSC. Three studies did not report the outcome in terms of intra-operative blood loss. Two of the studies [26,44] reported no statistically significant difference whereas one study [27] reported more intra-operative blood loss in E-NSM compared to C-NSM.

3.2.1.3. Complications. There were six E-BCS studies reporting on

Table 2
Studies on endoscopic assisted breast conserving surgery, operative methods and outcomes.

No	Author	Year of publication	Operative method	Incision placement	Wound protector	Posterior dissection	Subcutaneous or skin flap dissection	Average operation time (minutes, range or ± SD)
1	Tamaki	2001	E-BCS	Periareolar	Silicon ring	Retractor and bipolar scissor	Bipolar scissor	Total: 241 [190–315]; partial mastectomy: 84 [69–113]
2	Owaki	2005	E-BCS	5 cm axilla and periareolar for inner lesion	No data	Electrocauterizer	Two wire retractors and electrocauterizer	165 [45–260]
3	Lee	2006	E-BCS	2.5 cm axillary fold and periareolar	No data	Vein harvest and bipolar scissor	Tunneling method and bipolar scissor	163 [115–205]
4	Yamashita	2006	E-BCS	2.5 cm axillary and periareolar	Lap protector	Ultra retractor or vein harvest	Tunneling method and harmonic scalpel	173 ± 45
5	Yamashita	2008	E-BCS	2.5 cm axillary	Lap protector	Ultra retractor or vein retractor	Tunneling method and harmonic scalpel	45 min longer than C-BCS
6	Nakajima	2009	E-BCS	Midaxillary or periareolar	No data	Hirotech retractor	Tunneling method and bipolar scissor	Tis: 238 ± 47; T1: 223 ± 39; T2: 239 ± 52
7	Nakajima	2009	E-BCS	Midaxillary or periareolar	No data	Hirotech retractor	Tunneling method and bipolar scissor	177–236
8	Nakajima	2010	E-BCS	Midaxillary	No data	Hirotech retractor	Bladeless trocar (Endopath; Johnson & Johnson Medical, Arlington, TX, USA)	217 ± 59
9	Hong	2010	E-BCS	3.5 cm axillary skin crease and 3 cm periareolar incision	Alexis Wound Retractor (2–4 cm, XS; Applied Medical, Rancho Santa Margarita, USA)	Endosector LE	Tunneling method and bipolar scissor	144 (105–190)
10	Park	2011	E-BCS	3 cm axillary fold and periareolar	No data	Endosector LE	Electrocauterizer	BCS + SNB: 102.1 ± 22.9; BCS + Ax: 139.5 ± 30.3
			C-BCS					BCS + SNB: 102.38 ± 28.8; BCS + Ax: 122.49 ± 40.5
11	Takemoto	2012	E-BCS	Axilla and periareolar	No data	Preperitoneal distention balloon	Tunneling method and bipolar scissor	93 [77–106]
			C-BCS					69 [55–104]
12	Ozaki	2013	E-BCS	2.5 cm axillary fold and periareolar semicircular or lateral mammary line	Lap protector	Vein retracor and bipolar scissor	Tumesent technique	BCS: 130.5 ± 32.4; BCS + SNB: 148.1 ± 42.7; BCS + Ax: 189.7 ± 40.0
			C-BCS					BCS: 80.4 ± 21.8; BCS + SNB: 118.3 ± 46.4; BCS + Ax: 145.2 ± 48.1
13	Saimura	2013	E-BCS	3.0 cm axillary fold and periareolar semicircular	No data	Vein retractor and bipolar scissor	Electrocauterizer	Total: 167 [105–260]
14	Takahashi	2014	E-BCS	2–7 cm axillary incision and periareolar incision	Wrap protector	Vein retractor and bipolar scissor	Bipolar scissor	152.3 ± 21.7
			C-BCS					127.7 ± 35.6
15	Lai	2016	E-BCS	Axillary and periareolar incision	No data	Ultra retractor or vein harvest	Tumescent technique	193 ± 69 (65–325)

E-BCS: Endoscopic breast conserving surgery, C-BCS: Conventional breast conserving surgery.

the complications from this technique itself. Common complications documented in the studies include partial wound or skin flap necrosis in three studies [32,38,39], skin burn in a single patient [33] and infection in two studies [31,40]. Of particular concern would be wound infections in the two studies as the cases were all related to placement of absorbent synthetic fiber mesh (Vicryl mesh, Johnson & Johnson Co, US) wrapped in an absorbable adhesion barrier (INTERCEED, Johnson & Johnson Co, US) or oxidized cellulose cotton (Surgicel, Johnson & Johnson Co, US). The authors attributed the cause of infection to the overproduction of fluid induced by the absorbable meshes. Seven of sixty women who underwent E-BCS [31] had mesh infection which eventually resulted in mesh removal and unsatisfactory cosmetic outcomes. In E-NSM studies, two most common complications in most studies were implant-related (infection resulting in prosthesis loss and capsular contracture) as well as nipple areolar complex (NAC) ischemia or necrosis (Table 6).

3.2.1.4. Margins involvement. In E-BCS studies, all except one [21] study reported the rate of margin involvement. From 10 case series of E-BCS, the rate of positive margin ranged from 0 to 25% but 8 out of the 10 studies had a rate of margin involvement of less than 10%. Two studies with high margin involvement rate of more than 20% were both from the same centre and the authors clarified that no additional resection or surgery was performed in both studies as all of the margin-positive patients had relatively few tumour cells at the margins but received an additional 10-Gy tumour bed radiation boost. The authors further elaborated on the local recurrence rate between margin-positive and negative patients which did not show any statistically significant difference. Five cohort studies on E-BCS and C-BCS showed no statistically difference in terms of positive margins in three studies while the other two studies did not report and compare these data. In E-NSM studies, margin involvement was not commonly expected and as such, 6 studies did not report on margin involvement while 5 studies had no cases with margin involvement. One study [18] reported 8 cases with nipple margin involvement which had subsequent NAC removal while another study.

Table 3
Studies on endoscopic assisted breast conserving surgery, surgical outcomes, oncological outcomes and patient satisfaction rating.

No	Author	Year of publication	Op method	Post-operative drainage	Intra-operative blood loss (ml or g)	Margin positive	Complications	Follow up (months)	Local recurrence	Distant metastases	Death	Patient satisfaction rating
1	Tamaki	2001	E-BCS	Only in the case of ALND	192 [60–290] mL	0%	No data	No data	No data	No data	No data	No data
2	Owaki	2005	E-BCS	No data	150 ± 96.9 ml	No data	No data	No data	No data	No data	No data	Patient satisfaction: All patients are satisfied
3	Lee	2006	E-BCS	Yes	184 ± 130 mL	10% (2/20)	No data	No data	No data	No data	No data	Patient satisfaction: 89.5% satisfied
4	Yamashita	2006	E-BCS	Yes	174 ± 118	0%	No data	25	0%	0%	No data	Patient satisfaction rating: All patients are satisfied
5	Yamashita	2008	E-BCS	No data	No data	0%	No data	12	0%	0%	No data	No data
6	Nakajima	2009	E-BCS	No data	Tis: 116 ± 23; T1: 107 ± 27; T2: 141 ± 34	20.5% (113/551)	Skin necrosis: 4% Fat/muscle flap necrosis: 3.1%	35	4.2% (23/551)	4.5% (25/551)	1.3% (7/551)	No data
7	Nakajima	2009	E-BCS	No data	125–143 ml	14.3% (35/244)	No data	Stage I: 66.4 Stage II: 64.6	5.3%	6.4–10%	2.7–4.3%	No data
8	Nakajima	2010	E-BCS	No data	120 ± 49 g	18.9–25%	Skin necrosis: 2.4% Muscle flap necrosis: 0.6%	58.6	4.8% (8/168)	11.6% (19/168)	5%	Patient satisfaction: 81.6% satisfied
9	Hong	2010	E-BCS	No (if volume replacement technique used)	No data	4.5% (1/22)	Wound infection: 13.6% Skin retraction: 9.1%	No data	No data	No data	No data	No data
10	Park	2011	E-BCS	Yes	No data	5% (2/40)	No data	12	0%	No data	No data	No data
			C-BCS	Yes	No data	10.6% (85/681)	No data	12	0.3% (2/681)	No data	No data	No data
11	Takemoto	2012	E-BCS	No data	45 [10–80]	28.3% (17/60)	Mesh infection: 11.7% (7/60)	No data	No data	No data	No data	No data
			C-BCS	No data	100 [58–150]	25.5% (13/51)	No data					
12	Ozaki	2013	E-BCS	Yes	BCS: 51.6 ± 35.9	1.4% (1/73)	Partial wound necrosis: 5.4% Partial skin flap necrosis: 2.7% Postoperative bleeding: 1.4%	18.1 (12–30)	0%	0%	0%	Aesthetic outcome: 53.4% good
			C-BCS	Yes	BCS: 35.3 ± 29.7	18.9% (17/90)	No data	43.7 (14–70)	1.1% (1/90)	No data	0%	Aesthetic outcome:14.4% good
13	Saimura	2013	E-BCS	Only in the case of ALND	27 [5–80]	0%	Skin burn: 1.6%	No data	0%	0%	0%	No data
14	Takahashi	2014	E-BCS	Depends on volume excised	32.1 ± 28.0 ml	4%	No data	23 (9–40)	0%	0%	0%	Patient satisfaction score higher in E-BCS group
			C-BCS	No data	30.6 ± 26.1	3.3%	No data	No data	No data	No data	No data	
15	Lai	2016	E-BCS	No data	40.2 ± 20.2 ml (10–100)	6.5% (3/46)	No data	26.8 (3.3–68.6)	0%	0%	0%	No data

E-BCS: Endoscopic breast conserving surgery, C-BCS: Conventional breast conserving surgery, ALND: Axillary lymph node dissection.

[35] reported 3 cases with radial, superficial and deep margin involvement respectively with further surgery performed that showed no residual cancer or recurrence after a 3 years follow up. One study.

[27] had a single case of margin involvement with adjuvant radiotherapy administered.

3.2.2. Oncological outcomes

The follow up duration for E-BCS studies ranged from 12 to 66.4 months. 6 studies did not report data on follow up duration. In E-NSM studies, follow up duration ranged from 16.1 to 74 months while 4 studies did not record any follow up duration. Even though the follow up duration in both E-BCS and E-NSM studies was not adequate to ascertain long term oncological outcomes, short- or medium-term outcomes could be construed from the studies reviewed.

3.2.2.1. Local recurrence. Seven studies reported 0% local recurrence with duration of follow up ranging from 12 to 26.8 months [22,23,32–35,41]. Three studies by the same author [37–39] had a local recurrence rate of 4.2–5.3% with follow up duration of 34–66.4 months and the authors ascertained that local recurrence was higher in patients who had initial positive margins with subsequent radiotherapy but did not achieve statistical significance. Five studies did not have data pertaining to local recurrence. In E-NSM studies, seven studies reported 0% local recurrence rate with mean duration follow up ranging from 16.1 to 74 months [18,25,26,44,45,48,49]. In 2 cohort studies comparing E-NSM to C-BCS [26,44] with data on local recurrence, C-BCS reported a higher local recurrence rate compared to E-NSM but no statistical

Table 4
Studies on endoscopic assisted mastectomy, patient and tumour characteristics.

No	Author	Year of publication	Journal	Number of patients/ Breasts treated	Operative method	Average tumour size (cm, range or ± SD)	Clinical T stage or Clinical stage, n (%)
1	Nakajima	2002	Biomed Pharmacother	17	E-NSM	No data	Tis: 2 (11.8); T1: 1(5.9); T2: 11 (64.7); T3: 3(17.6)
2	Kitamura	2002	Surgery	20/21	E-NSM	2.1 ± 1.2	Tis,T1: 14 (66.7); T2: 6 (28.6); T3: 1 (4.7)
				24/25	C-NSM	2.1 ± 1.0	Tis,T1: 17 (68); T2:8 (32); T3: 0
3	Ho	2002	Surg Endosc	9	E-NSM	No data	Tis: 5; T1: 2; T2: 2
4	Ito	2008	ANZ J Surg	33	E-NSM	No data	Tis: 29 (87.9); T1: 3(9.1); T2: 1(3.0)
5	Fan	2009	Chinese Med J	43	E-NSM	2.7 ± 0.9	Stage 1: 15 (34.8); Stage 2: 22 (51.2); Stage 2A: 6 (14)
				54	C-BCS	2.6 ± 0.9	Stage 1: 22 (40.7); Stage 2: 27 (50); Stage 2A: 5 (9.3)
6	Sakamoto	2009	Ann Surg Oncol	87/89	E-NSM	2.1 (0.1–5.6)	Tis/T1: 47 (53); T2: 40 (45); T3: 2 (2.2)
7	Tukenmenz	2014	J Laparoendosc Adv Surg Tech	10/11	E-NSM	1.4 ± 0.6 (0.8–2.9)	No data
8	Lai	2015	Surgical Innovation	48/49	E-NSM	2.1 ± 1.4	Stage 0: 17 (34.7); Stage 1: 18 (36.7); Stage 2: 12 (24.5); Stage 3: 2 (4.1)
9	Wang	2016	Journal of Surgical Oncology	24	E-NSM	1.7 ± 0.9 (0.4–3.0)	Stage 1: 15 (62.5); Stage 2A: 6 (25); Stage 2B: 3 (12.5);
				25	C-NSM	1.9 ± 0.7 (0.8–3.4)	Stage 1: 12 (48); Stage 2A: 8 (32); Stage 2B: 5 (20)
10	Lai	2016	PLOS One	269	E-NSM/E-SSM	2.2 ± 1.8 (0.1–8.5)	Stage 0: 66 (24.2); Stage 1: 88 (32.2); Stage 2: 117 (42.9); Stage 3: 2 (0.7)
11	Hung	2017	PLOS One	134	E-NSM	No data	Tis: 26 (19.4); T1: 50 (37.3); T2: 46 (34.3); T3: 10 (7.5)
12	Wang	2017	JSLS	30	E-NSM	No data	Stage 0: 5 (16.67); Stage 1: 4 (13.33); Stage 2A: 14 (46.67); Stage 2B: 3 (10.00); Stage 3A: 4 (13.33)
				30	C-NSM	No data	Stage 0: 5 (16.67); Stage 1: 4 (13.33); Stage 2A: 13 (43.33); Stage 2B: 1 (3.33); Stage 3A: 7 (23.33)
13	Du	2017	Scientific Reports	157	E-NSM	No data	Stage 1: 36 (22.9); Stage 2A: 65 (41.4); Stage 2B: 32 (20.4); Stage 3A: 24 (15.3)
				189	C-BCS	No data	Stage 1: 70 (37); Stage 2A: 81 (42.9); Stage 2B: 24 (12.7); Stage 3A: 15 (7.9)
14	Lai	2018	Ann Surg Oncol	41/50	E-NSM	Invasive tumour: 2.3 ± 1.8 (0.1–7.3) In-situ tumour: 2.6 ± 1.7 (0.2–5.7)	Stage 0: 15 (30); Stage 1: 10 (20); Stage 2A: 10 (20); Stage 2B: 4 (8)

E-NSM: Endoscopic nipple sparing mastectomy, C-NSM: Conventional nipple sparing mastectomy.

significance was achieved.

3.2.2.2. Distant metastasis. There were altogether 9 E-BCS studies reporting on distant metastasis in which 6 studies described no distant metastasis in their cohort with mean follow up duration from 12 to 25 months. Another 3 studies from the same institution reported a distant metastasis rate of 4.5–11.6% and a mean follow up duration of 35–66.4 months. In all E-NSM studies, 4 studies reported no distant metastasis within their cohort whereas 7 other studies did not present these data. Three other studies reported distant metastasis ranging from 0.3 to 10% with only one study [35] going into details of a single patient in the cohort to develop brain metastasis 8 months after operation despite completing adjuvant chemotherapy and radiotherapy. The recurrence was attributed to poor tumour biology as patient had bilateral triple negative breast carcinoma.

3.2.2.3. Overall survival. Overall survival was reported in 7 E-BCS studies whereby 4 studies reported overall survival of 100% and 3 studies from the same institution published over a 2 years period described overall survival of 95–98.7% over a mean follow up duration of 35–66.4 months. In terms of E-NSM studies, 6 studies reported overall survival of 100% whereas 2 studies reported overall survival of 99.6% [35] and 96.8%
[44] respectively.

3.2.2.4. Cosmetic outcomes and satisfaction

Cosmetic outcomes and patients' satisfaction were assessed in 6 E-BCS and 10 E- NSM studies (Tables 3 and 6). There were no standardized assessment methods and the cosmetic outcomes were assessed with the following assessment methods:

I Five-item-by-4-step method (ABNSW), consisting of five items (Asymmetry, Breast shape, Nipple shape, Skin

Condition and Wound scar). Each item was evaluated with four-point scale (0, poor; 1, fair; 2, good; and 3, excellent). Scores greater than 11 points were considered good or excellent [22,49].

II Japanese Breast Cancer Society (JBCS) classification, consisting of eight items (breast size, breast shape, breast scar, hardness, nipple/areolar size, shape, nipple/areolar color, nipple position, and inframammary line). Each item was evaluated with a 3-point system (2 points, good; 1 point, fair; and 0 points, poor) or 2-point system (1 point, good; 0 point, poor), and total scores were defined as "excellent" for scores of 11–12, "good" for scores of 8–10, "fair" for scores of 5–7, and "poor" for scores of 0–4 [32].

III Four-point scoring system (excellent, good, fair, or poor) [19,27,44].

IV Patient self-assessment satisfactory index [46].

V Subjective assessment by physician or patient [21,28,34,43,47,48].

VI Five-item assessment (appearance of the surgical scar; breast size; breast shape; nipple position; and areolar shape)

And comparison with contralateral breast with a 4-point scale (excellent (0), when there was no difference between both sides; good (1), when there was only a slight difference; fair (2), when a marked difference was present, which could be masked with clothing; and poor (3), when the difference was disturbing) [26].

VII Three-item assessment (size and conspicuousness of the

surgical scar; symmetry in terms of size and shape; overall satisfaction) on a 3-point scale (good, fair, poor) [39].

VIII 10 questions self-reported questionnaire (pre- and post-op breast shape, nipple position and volume symmetry of both breasts) on a 4-item scale (very satisfied, satisfied, fair, dissatisfied) [45].

In general, most of the patients in E-BCS or E-NSM cohorts were satisfied with their post-operative cosmetic outcomes irregardless of assessment scales used. However, the evaluations were mostly performed at approximately 3–6 months after operation and perhaps a better time point for evaluation of long-term cosmetic outcomes should be performed after radiotherapy or at least 2–3 years after surgery.

4. Technical aspects (Tables 1, 2, 4 and 5)

4.1. Selection criteria or indications

For all E-BCS and E-NSM studies, selection criteria based on average tumour size were all limited to T2 lesion and below. As for clinical stage, all of the patients enrolled in E- BCS studies were Stage 2 and below whereas for E-NSM studies, majority of patients were in Stage 2 and below except for 3.2% (30/936) of patients in 4 studies [35,43,44,48]. Breast size was used as a selection criteria for E-NSM in 3 studies [44,45,49]. Patients with small to medium-sized breast (A, B, or C cup) were reported to benefit the most from E-NSM. Patients with large (D cup and above) and ptotic breast were not good candidates for E-NSM due to technical feasibility, higher risk of nipple-areolar complex (NAC) necrosis and suboptimal cosmetic result [45]. Contraindications in all E-BCS studies include severe co-morbid conditions such as heart disease, liver dysfunction, renal failure, or a poor performance status, tumour extension to the nipple or direct invasion to the skin and pectoralis major, axillary lymph node metastasis, multifocal/multicentric lesions and micro calcified lesions. These were similar to contraindications in E-NSM studies except for multifocality or multicentricity in which mastectomy might be more suitable in terms of oncological feasibility as reported in 5 studies [18,25,27,28,49] as one of the inclusion criteria for enrolment. In one particular E-BCS study [32], tumour resection volume of more than 20% of the whole breast volume and tumour in the lower pole region were excluded due to difficulties in achieving desirable cosmesis. Clinically positive axillary nodes were also contraindicated in five studies [19,22,33,36,41].

4.2. Pre-operative diagnostic imaging and intra-operative marking of surgical margins

In E-BCS studies, nine out of fifteen studies reported using magnetic resonance imaging (MRI) in addition to conventional breast imaging (mammography, MMG and ultrasound, US) [19,22,23,32,33,37,39–41]. One study reported use of conventional breast imaging with no mention of routine use of MRI for BCS cases [35]. The remaining five studies did not mention any diagnostic imaging tools. With regards to pre-operative marking of resection margins, eleven studies utilized either methylene blue or indocyanine green dye to mark resection margins under ultrasound guidance with at least a 2 cm margins [19,22,23,31,33–35,37–39,41]. One study reported the use of MRI findings to guide intra-operative US-guided planning of resection margins and mobilization of breast parenchyma. For non-palpable tumors with calcifications identified using MMG, a hook wire was initially inserted under stereotactic guidance. Thereafter, US-guided planning was performed. The authors also marked the penetrating branch of the internal thoracic vessels in the parasternal area by US routinely in order to preserve blood supply to the.

remaining breast parenchyma after resection [32]. Although marking of margins were not.

routine in endoscopic nipple sparing mastectomy cases, it is interesting to note that two out of fourteen studies in this review reported using methylene blue dye in marking out the superficial margin of tumour [26] as well as nipple-areolar complex [43] respectively for intra-operative frozen section analysis in order to reduce the probability of involved margins in final histopathology.

4.3. Operative method/technical considerations

4.3.1. Skin incision placement

In terms of incision placement, combination of an axillary and periareolar incision was most commonly used in nine out of fifteen E-BCS studies [19,22,31–35,40,41]. In studies utilizing dual incision, the small axillary incision was used for axillary staging procedures and dissection of the posterior surface of the breast parenchyma off pectoralis major fascia while the periareolar incision was used for the development of skin flap. Removal of resected specimen was performed through either incision. Other types of incisions used were single incision placed in the axillary fold, peri-areolar, mid-axillary or lateral mammary region. One study [23] reported a transaxillary retro-mammary approach to wide local excision to preserve NAC sensation from sparing of a periareolar incision. Another study [37] utilized either a mid-axillary or periareolar incision depending on location of tumour and the same author subsequently reported the use of single axillary incision for latissimus dorsi (LD) flap harvest in a separate study [39]. For studies on E-NSM, six studies [18,27,28,43,45,47] utilized a 3–6 cm single axillary incision while four other studies reported dual incision over at axillary fold and peri-areolar region [25,35,46,48]. Three studies routinely performed E-NSM through multiple (3–4) 5 mm–12 mm ports [26,44,49]. The choice of incisions used in E-NSM seemed to be based on a few considerations, namely to provide easier and direct access to axillary staging procedure [18,27,43,47] or reduce rate of NAC ischaemia/necrosis [28,45] for a single axillary incision, while studies which utilized dual incisions had the peri-areolar incisions for precise dissection of sub-nipple or sub-areolar tissue for intra-operative frozen section analysis to prevent possible nipple involvement. One study [27] reported sending the tumour surface for intra-operative frozen section analysis to reduce rate of margin involvement.

4.3.2. Use of insufflation/retraction (for E-NSM cases)

All studies on E-BCS used retraction-assisted method in performing wide local excision. For studies on E-NSM, eight studies used retraction method to aid in dissection while another five studies used gas insufflation with carbon dioxide intra-operatively (Tables 2 and 5). Insufflation technique in E-NSM was first reported in 2002 [27] but it was only performed in the first 2 cases in the series whereas retraction method was used for subsequent cases. Three subsequent studies which utilized insufflation technique had E-NSM performed through multiple ports [26,44,49]. Single port insufflation technique was first reported in 2014 [28]. Authors in two studies using carbon dioxide insufflation proposed that the inflation helped in the dissection by pushing away the Cooper's ligaments [28] and improved visualization by reducing bleeding through positive pressure [45].

4.3.3. Dissection of posterior portion of breast parenchyma off pectoralis major fascia

Dissection of the posterior portion of breast parenchyma was normally performed via an axillary incision after completion of axillary staging procedure. In all but one E- BCS studies, endoscopic dissection was performed with various retraction devices (Vein harvest, Ultra Retractor, Vein Retractor, Endosector LE and Hirotech Retractor) along with a bipolar scissor. The advantage of using an endoscopic retraction device was to allow for a magnified view and adequate space for dissection. One other study.

[31] reported the use of a preperitoneal distention balloon for creation of space before dissection with electrocautery was performed. For E-NSM studies, six studies described the use of endoscopic retraction device for this part of the operation as well whereas three studies reported the use of pre-peritoneal distension balloon [18] and other laparoscopic instruments & energy devices (Table 5) respectively [26,28]. The similarities between the two studies using laparoscopic instruments and energy devices were the use of carbon dioxide insufflation to aid in adequate space creation.

4.3.4. Subcutaneous or skin flap development

In this step of the operation, the most commonly employed dissection technique for both E-BCS and E-NSM studies involved using a bladeless trocar equipped with an endoscope and bipolar scissors, energy device, or an electric cautery device. Firstly, the bladeless trocar was used to separate the breast parenchyma from the overlying skin or subcutaneous tissue under endoscopic guidance which was commonly known as the 'subcutaneous tunneling method'. Subsequent steps involved identifying and dissecting the septa created between the tunnels from the subcutaneous tunneling with either bipolar scissors, energy devices or electric cauterizer with or without endoscopic guidance. In 2 studies, subcutaneous infiltration of a tumescent solution preceded the subcutaneous tunneling and dissection of skin flap to aid in the dissection and reduce bleeding [32,35]. Skin-retraction devices, whereby the skin was lifted up with external retraction device, wires or sutures were used in two E-BCS [21,23] and one E-NSM [43] studies respectively.

4.3.5. Resection of the mammary gland and specimen retrieval

After adequate skin flap development as well as dissecting the posterior portion of breast parenchyma off pectoralis major fascia, dissection of the breast parenchyma in either E-BCS or E-NSM studies was commonly performed with bipolar scissors, energy devices or electro-cauterizer with the help from and endoscopic light retractor. For E-NSM studies using insufflation technique, mastectomy was performed with either laparoscopic hook with monopolar diathermy [26], energy devices [28] or laparoscopic scissors with monopolar diathermy [45]. Depending on the location of tumour, it can be performed via the peri-areolar or axillary incision and specimen can be received from either incisions. One study [44] detailed the sequence of dissection as follows: outer lower quadrant - outer upper quadrant - inner lower quadrant - inner upper quadrant, possible due to the ease of access from placement of ports.

4.3.6. Placement of surgical clips (for E-BCS studies)

Clips were routinely placed in the resection cavity after wide local excision. In E- BCS studies reviewed, only two studies reported routine placement of surgical clips in the resection cavity [32,41].

4.3.7. Reconstruction of the breast

Partial Reconstruction after E-BCS.

In E-BCS studies reviewed, partial reconstruction techniques were performed to repair the cavity after a wide local excision. The techniques reported were classified as below:

a. Volume displacement [19,21,32,33,36,38,41].
   - Seven E-BCS studies repaired wide excision resection cavities with volume displacement techniques, whereby surrounding breast parenchyma were dissected, mobilized and approximated under endoscopic guidance. A few keypoints to ensure adequate defect coverage and acceptable cosmesis with no increased complications include tension free approximation [19], and use of volume replacement techniques in cases where the wide excision volume was <30% of total breast volume [38]. Another study [32] recommended adequate dissection of the retromammary space during wide excision to ease subsequent mobilization and remodeling.
b. Volume replacement [38].
   - One study reported using local tissue flap (latissimus dorsi or lateral tissue flap) for defects which were more than 30% of the total breast volume.
c. Filling method [22,23,31].
   - Three studies demonstrated an interesting technique whereby wide excision defect was filled with an absorbent synthetic fiber mesh (Vicryl mesh, Johnson & Johnson Co, US) wrapped in an absorbable adhesion barrier (INTERCEED, Johnson & Johnson Co, US) or oxidized cellulose cotton (Surgicel, Johnson & Johnson Co, US)

5. Reconstruction after E-NSM

All E-NSM studies except one described immediate reconstruction after mastectomy. The authors [25] clarified that immediate reconstruction was rarely performed in the centre and delayed reconstruction approximately 3–4 years after the index operation was the preferred option for most of the patients.

a. Implant or tissue expander reconstruction
   - 10 studies performed immediate implant or tissue expander reconstruction after E-NSM [18,26–28,35,42–44,46,49]. There was no mention of the use of any

synthetic or biologic mesh and there was only 1 study [28] which described suturing of free muscle edges laterally.

b. Autologous tissue
   - Six studies reported the use of autologous tissue for reconstruction of mastectomy defect with tranversus rectus abdominis muscle (TRAM) being the most commonly utilized flap in four studies [35,42,45,48], whereas latissimus dorsi (LD) muscle was used in one study [47] and local tissue flap in another [43]. There was, however, no mention of the average breast size or volume of mastectomy specimen removed in the 2 latter studies as a LD or local tissue flap for a full reconstruction may only be suitable for small volume resection.

5.1. Postoperative drainage

In E-BCS studies, routine postoperative drain placement was performed in four studies [19,22,32,41] while in three other studies, drain placement was reserved for selective cases whereby axillary dissection was performed [33,36] or dependent on the volume of breast parenchyma excised [34]. One study reported that no drainage was done in cases of volume replacement in order to preserve breast contour [40]. Seven other E-BCS studies did not discuss these data. In E-NSM studies, twelve out of fourteen studies

Table 5
Studies on endoscopic assisted mastectomy, operative methods and outcomes.

No	Author	Year of publication	Operative method	Incision placement	Wound protector or port used	Insufflation/ Retraction	Posterior dissection	Subcutaneous dissection	Average operation time (minutes, range or ± SD)	P-value	Reconstruction
1	Nakajima	2002	E-NSM	4–5 cm mid-axillary line	Visiport (US Surgical, USA)	Retraction	Vein Harvest (J&J, USA)	Bipolar scissor	265 min longer than C-NSM	No data	LDMF in 14 patients: None in 3 patients
2	Kitamura	2002	E-NSM	6 cm vertical incision at mid-axillary line	Lap-protector (Hakko Co, Japan)	CO2 for first 2 cases; gasless for the remaining cases	No data	No data	237 ± 60	0.001	Saline prosthesis
			C-NSM	No data	No data		No data	No data	176 ± 32		
3	Ho	2002	E-NSM	Single axillary incision in 6 cases; Axillary and circumareolar incision in 3 cases	Visiport Plus (Covidien, Mansfield, MA)	Retraction	Endoscopic dissector	Harmonic scalpel	234 (195–275)		Saline prosthesis
4	Ito	2008	E-NSM	5 cm axillary skin crease	Visiport Plus (Covidien, Mansfield, MA)	Retraction	Pre-peritoneal distension balloon (US Surgical, USA)	Tunneling method and harmonic scalpel	NSM alone: 234 ± 53 NSM + SNB + IPBR: 257 ± 29 NSM + Ax + IPBR: 290 ± 53		Saline prosthesis
5	Fan	2009	E-NSM	3 × 5 mm incisions (axilla crease, midaxillary, anterior axillary)	5 mm trocar	CO2 insufflation at 8 mmHg	Laparoscopic hook	Laparoscopic hook	168 ± 32	<0.01	Saline prosthesis
			C-BCS	Fusiform incision	–	–	–	–	139 ± 37		–
6	Sakamoto	2009	E-NSM	3 cm axillary skin crease and periareolar incision	Visiport Plus (Covidien, Mansfield, MA)	Retraction	Ultra Retractor (J&J, USA)	Endopath Xcel Bladeless Trocar (J&J, USA) via tunneling method	No data		None
7	Tukenmenz	2014	E-NSM	3–6 cm single axillary incision	SILS™ port (12 mm; Covidien, Norwalk, CT)	CO2 insufflation at 8 mmHg	Endo Grasp™ (Autosuture™, Covidien), an endoscissors (Endo MiniShears™ 5-mm instrument with unipolar cautery; Covidien), LigaSure™ V (Valleylab Inc., Boulder, CO), and Harmonic ACE™ curved shears (Ethicon Endo-Surgery, Cincinnati, OH)		250 (140–330)		Silicone prosthesis
8	Lai	2015	E-NSM	3 cm oblique axillary incision and periareolar incision	No data	Retraction	Ultra Retractor (J&J, USA)	Endoscissors, bipolar scissors (PowerStar, J&J, USA), and/or harmonic scalpel as well as tunneling method with endoscissors, bipolar scissors (PowerStar, Johnson & Johnson KK), and/or a harmonic scalpel	E-NSM alone: 238 ± 61 (85–290) E-NSM + TRAM: 634 ± 123 (385–780)		TRAM flap
9	Wang	2016	E-NSM	2 × 10–12 mm incision (anterior axillary and midclavicular); 1 × 5 mm posterior axillary line	5 mm and 12 mm optical trocars (Olympus Co., Tokyo, Japan)	CO2 insufflation at 8 mmHg	No data	No data	131.6 ± 18.7 (102–165)	0.024	One-stage breast reconstruction in 6 patients
			C-NSM						99.2 ± 12.7 (75–126)		
10	Lai	2016	E-NSM/E-SSM	3 cm oblique axillary incision as a single incision or with an additional semi-circular peri-areolar incision	No data	Retraction	Ultra Retractor (J&J, USA)	Endoscissors, bipolar scissors (PowerStar, J&J, USA), and/or harmonic scalpel as well as tunneling method with endoscissors, bipolar scissors (PowerStar, Johnson & Johnson KK),	Mean mastectomy time: 219 ± 85 (60–540) Mean reconstruction time: 154 ± 138 (35–770)		Prosthesis: implant, expander; TRAM

Table 5 (*continued*)

No	Author	Year of publication	Operative method	Incision placement	Wound protector or port used	Insufflation/ Retraction	Posterior dissection	Subcutaneous dissection	Average operation time (minutes, range or ± SD)	P-value	Reconstruction
								and/or a harmonic scalpel Tumescent technique			
11	Hung	2017	E-NSM	No data	No data	No data	No data	No data	Learning phase: 275.33 ± 46.35 Mature phase : 228.91 ± 54.32	<0.05	Gel implant: 61 cases TRAM: 9 cases
12	Wang	2017	E-NSM	6–8 cm axillary incision	No port	Retraction	No data	Skin-lift system (including wires, frames, and support structure; Mizuho, Tokyo, Japan)	No data		Implant: 19 cases Skin flap: 9 cases
			C-NSM	Axillary incision and additional periareolar incision							Implant: 18 cases Skin flap: 10 cases
13	Du	2017	E-NSM	4× incisions of 1 cm each (axilla, outer edge of areola, outer edge of breast at NAC level, anterior axillary line)	No data	CO2 insufflation at 10 mmHg	No data	No data	197	0.001	Implant
			C-BCS	Depending on location of tumour					165		No data
14	Lai	2018	E-NSM	2.5 − 5 cm oblique axillary incision	No port	Retraction	Ultra Retractor (J&J, USA)	Optical bladeless trocar (Xcel, Johnson & Johnson, Tokyo, Japan) under endoscopic guidance (tunneling method) or blindly with tunneling of Metzenbaum scissor	244.3 ± 82.8 (138 −425)		Gel implant

C-BCS: Conventional breast conserving surgery, E-NSM: Endoscopic nipple sparing mastectomy, E-SSM: Endoscopic skin sparing mastectomy, LDMF: Latissimus dorsi myocutaneous flap, NAC: Nipple areolar complex, CO2: Carbon dioxide, TRAM: Tranverse rectus abdominis muscle.

had routine placement of drains while two other studies [18,42] did not discuss post-operative drainage. The numbers and locations of drains differed between studies and were detailed here; one drain in 2 studies [44,46], 1 drain in the.

mastectomy pocket and 2 drains in TRAM donor site in one study [48], 1 drain in mastectomy pocket and 1 drain in the subpectoral pocket for studies with immediate tissue expander/implant reconstruction [26–28,35,45], 2 drains in mastectomy pocket and 1 drain in LD donor site [47], 2–3 subcutaneous drains with no specified locations in three other studies [25,43,49].

6. Discussion

Endoscopic-assisted breast surgery (EABS) has developed over the years and it is therefore important to review all articles in the current literature to ascertain the trend, development of techniques as well as outcome evaluations over the past 20 years since it was first developed in the late 1990's.

Oncological and therefore patients' outcomes are important considerations when it comes to the development of a technique used in cancer treatment. Cohort studies comparing margin involvement between EABS and conventional techniques did not show any significant difference and this was also subsequently shown to be similar in terms of oncological outcomes. One thing to note however was that in cases with involved margins after E-BCS, most patients did not receive further excision but instead had radiotherapy with additional boost to the resection cavity and this did not result in higher rate of local as well as distant recurrence compared to patients who either underwent further excision or had negative margins. Short- and medium-term oncological outcomes in EABS has been shown to be similar compared to conventional techniques but long-term oncological outcomes would be important to place EABS as one of the standards of care for breast cancer care.

Through this review, there are some advantages of endoscopic-assisted breast surgery (EABS) whether it is in breast conserving surgery or nipple sparing mastectomy. Firstly, EABS allows for better incision or scar placement in inconspicuous areas thereby leading to better cosmesis. Secondly, it allows for tumour resection with adequate margins and hence no compromise on short and medium-term oncological outcomes. Thirdly, it offers better visualization with the aid of light handle retractors and allows for better precision when it comes to wide excision.

On the other hand, EABS has its inherent disadvantages as more equipment is required with additional time in the set-up and conduct of the operation. This leads to increased operative duration if compared to conventional surgery. However, cohort studies have shown that the operative time could be reduced after overcoming initial learning curve and there was no increased risks of complications and adverse outcomes as a result of the longer operative time. Increased cost is also another possible disadvantage as there are disposable instruments used in the conduct of the operation compared to conventional surgery. The solution to this may be the use of re-useable equipment but it would be of great value to have a cost-effectiveness analysis looking at the average cost of EABS in the long run.

Studies conducted over the years have shown the technical feasibility of EABS in achieving equivalent surgical outcomes to

Table 6
Studies on endoscopic assisted mastectomy, surgical outcomes, oncological outcomes and patient satisfaction rating.

No	Author	Year of publication	Operative method	Post-operative drainage	Intra-operative blood loss (ml or g)	Margin positive, n (%)	Complications, n (%)	Follow up (months)	Local recurrence	Distant metastases	Death	Patient satisfaction rating
1	Nakajima	2002	E-NSM	Yes	No data	No data	No severe complications	No data	No data	No data	No data	All patients were pleased with cosmetic results
2	Kitamura	2002	E-NSM	Yes	356 ± 286 g	1 (4.8)	Prosthesis related complications: 1(4.8)	19.2 ± 9.8 (5.8–35.2)	No data	No data	0%	Excellent: 85.6% Good: 4.8%
			C-NSM	Yes	189 ± 72 g	2 (8.0)	Prosthesis related complications: 3(12.0)		No data	No data	0%	Excellent: 60% Good: 16%
3	Ho	2002	E-NSM	Yes	135 ml	0%	Skin bruising: 2	No data	No data	No data	No data	Patient satisfaction rating: All patients were satisfied
4	Ito	2008	E-NSM	No data	E-NSM alone: 230 ± 141 ml E-NSM + SLNB + IPBR: 138 ± 97 E-NSM + ALND + IPBR: 210 ± 168	Positive nipple margin: 8 (24.3%)	Implant infection: 3 (9.1) Nipple necrosis: 3 (9.1)	51.2 (16–86)	0%	0%	0%	No data
5	Fan	2009	E-NSM	Yes	115 ± 44	0%	Nipple or skin flap necrosis: 5 (11.6)	16.9 ± 11.2	0%	0%	0%	Satisfactory outcome: 88.4%
			C-BCS	Yes	102 ± 48	0%	Seroma: 6 (11.1)	20.1 ± 11.9	5.9%	0%	1.9%	Satisfactory outcome: 92.6%
6	Sakamoto	2009	E-NSM	Yes	No data	No data	Overall: 20 (22) Infection: 1 (1.1); Skin flap necrosis: 3 (3.4); Nipple necrosis: 16 (18)	52 (16–80)	0%	10%	0%	No data
7	Tukenmenz	2014	E-NSM	Yes	No data	0%	Nipple sloughing: 3 (27.3); Haematoma: 1 (9); Implant infection: 1 (9)	No data	No data	No data	No data	All patients were satisfied
8	Lai	2015	E-NSM	Yes	182 ± 71 ml	0%	NAC partial ischaemia/ necrosis: 4 (10.3); Areolar wound delayed healing: 7 (14.3); TRAM partial fat necrosis: 6 (12.2)	19.5 ± 11.6 (3–53)	0%	No data	No data	Patient satisfaction: 98%
9	Wang	2016	E-NSM	Yes	No data	No data	NAC necrosis: 2 (8.3)	16.1 (14.2–19.1)	0%	0%	0%	Excellent/good: 95.8%
			C-NSM	Yes	No data	No data		No data	No data	No data	No data	Excellent/good: 76%
10	Lai	2016	E-NSM/E-SSM	Yes	104.5 ± 74.9 ml (20–650)	1.1% (3/269)	Prosthesis loss: 3 (2.1); NAC partial ischaemia: 17 (8.5); NAC complete necrosis: 8 (4)	26.8 (3.3–68.6)	0.9%	0.3%	0.4%	No data
11	Hung	2017	E-NSM	No data	No data	No data	No data	No data	2.2%	No data	No data	No data
12	Wang	2017	E-NSM	No data	No data	No data	No data	27.77 ± 20.43	No data	No data	No data	Patient satisfaction: 29 (96.67)
			C-NSM	No data	No data	No data	No data	43.22 ± 19.80	No data	No data	No data	Patient satisfaction: 29 (96.67)
13	Du	2017	E-NSM	Yes	95 ml	No data	Infection: 5 (3.18); Skin edge necrosis: 11 (7.01); Lymphedema: 15 (9.55)	74 (52–111)	0%	4.5%	3.2%	Excellent/good: 69.43%
			C-BCS	Yes	83 ml	No data	Infection: 8 (4.23); Skin edge necrosis: 16 (8.46); Lymphedema: 23 (12.16)		3.2%	1.6%	3.2%	Excellent/good: 58.2%
14	Lai	2018	E-NSM	Yes	74.5 ± 47.7 ml (25–250)	0%	NAC partial ischemia: 1 (2); Seroma: 2 (4)	21.6 ± 11.3 (1–42.4)	0%	0%	0%	Patient satisfaction with: Scar appearance: 97.2% Wound length: 94.4% Wound position: 94.4%

C-BCS: Conventional breast conserving surgery, E-NSM: Endoscopic nipple sparing mastectomy, E-SSM: Endoscopic skin sparing mastectomy, IPBR: Immediate prosthesis breast reconstruction, ALND: Axillary lymph node dissection, SLNB: Sentinel lymph node biopsy, NAC: Nipple areolar complex, TRAM: Tranverse rectus abdominis muscle.

conventional surgery. As discussed earlier, the increased operative time in EABS did not result in increased complications and could be reduced after overcoming initial learning curve. There was no clinically or statistically significant increase in terms of intra-operative blood loss. Common complications associated with EABS were similar to conventional techniques and include skin flap or nipple necrosis and this could be attributed to the skin flap thickness and therefore blood supply to the flap especially in cases where the dermis was exposed. Studies using tumescent for skin flap reported ease of dissection and maintenance of adequate skin flap thickness. Nipple necrosis were mostly reported in cases whereby peri-areolar incision was used and studies with sparing of peri-areolar incision reported lower rate of nipple necrosis. One particular complication of concern would be the high rate of wound infection reported in two studies with the use of absorbable synthetic material or meshes as a volume replacement method in E-BCS. Even though the authors reported subsequent preventive measures such as the use of peri-operative prophylactic antibiotics and frequent changing of surgical gloves, the incidence of infection has not been completely eradicated and the use of these materials should be observed with caution.

In terms of aesthetic outcomes and patient satisfaction assessment, most patients were regarded as being satisfied with the cosmesis especially in terms of scar placement and length of skin incision. However, most of the assessments were done at about 3–6 months after operation and perhaps a repeat assessment should be performed at approximately 2–3 years after the initial operation such that remodeling of breast parenchyma would have been completed and also in cases where adjuvant radiotherapy is required.

Undoubtedly, there are many factors involved in successfully performing EABS. Patient selection is by no means the most important factor to consider when considering EABS. Patients suitable for EABS in general include early breast cancer with no obvious involvement of skin or muscle and specific to E-BCS, must have tumour that is less than 20% of the total breast volume to maintain satisfactory cosmesis especially if volume displacement techniques are used. For E-NSM, cases with possible nipple involvement or extension on pre-operative imaging must be viewed with caution and treated as either a relative contraindication or patient must be counselled regarding the risks of NAC removal if NAC were found to be involved either on routine histopathology or intra-operative frozen section analysis. Important adjuncts such as pre-operative breast magnetic resonance imaging (MRI), intra-operative ultrasound, specimen radiography and frozen section analysis of the margins should be made routine and available in the surgical planning of EABS to ensure resection with adequate margins. The use of colored dye for planning of surgical margins is an ingenious method to reduce the rate of involved margins while not removing excessive amount of breast tissue. In addition, the use of neoadjuvant therapy in downsizing tumour while assessing tumour biology may be important in patients initially deemed unsuitable for EABS.

In conclusion, EABS is definitely promising with comparable oncological, surgical and aesthetic outcomes to conventional techniques and there has been great progress with change of techniques over the years to overcome initial complications or difficulties associated with EABS. However, standardization of techniques, practice guidelines and objective outcome assessments methods might pave the way for better conduct of EABS and place EABS as one of the standards of care for breast cancer care.

Conflicts of interest

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Ethics approval

Not required.

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