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AN INSTITUTIONAL EXPERIENCE

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The White Memorial Medical Center (WMMC) is a private community hospital located in East Los Angeles, California. Established in 1913 by the Seventh-day Adventist Church, the WMMC promotes its mission to provide quality health services, medical and health education, and outreach services to the Los Angeles community, with care and compassion. With a capacity of 369 beds, WMMC serves a densely populated community, with more than two million people living within a 5-mile radius of the Medical Center. The demographics of this service area reflect an ethnic homogeneity, whereby 70.7% of residents are Hispanic and 7.5% Asian. The population can be characterized as low income, with about 62% of households having an annual income of $25 000 or less[1]. As a direct result of this circumstance, government-sponsored health care is relied upon to a great extent and fully insured coverage is relatively uncommon.

The WMMC conducts graduate and continuing medical education activities as an affiliate institution for Loma Linda University School of Medicine. Four residency-training programs are in place: Obstetrics and Gynecology, Family Medicine, Internal Medicine, and Pediatrics. The Department of Obstetrics and Gynecology is comprised of 25 medical staff members, seven of whom serve as full-time faculty for the residency-training program. The remaining medical staff members serve as consulting and part-time faculty. The resident house staff participates in the care of all patients and its members are an integral part of the health-care team. The obstetric service performs approximately 3500 deliveries per year. As is the case in obstetric practice of this magnitude, hemorrhage is encountered and often is unanticipated.

In the spring of 1997, the chief obstetric resident encountered an instance of postpartum hemorrhage, which required life-saving emergency hysterectomy in a young woman. Moved by her concern for her patient, by her observation of the morbidity associated with postpartum hemorrhage, and her intellectual curiosity, she conducted a literature search and encountered the publication 'The B-Lynch surgical technique for the control of massive postpartum hemorrhage: an alternative to hysterectomy? Five cases reported', published in the *British Journal of Obstetrics and Gynaecology* in March 1997, by B-Lynch and associates[2]. This article was then presented to other residents and staff at Journal Club, thus introducing the then new concept of uterine compression by brace suture. In the years since 1997, the operation has been used regularly.

CASE SERIES

The study design was as follows: cases with B-Lynch suture utilization for severe postpartum hemorrhage were identified, from March 1, 1997 to March 31, 2005, at WMMC. Case records were reviewed, and postoperative follow-up was conducted by telephone interview and outpatient clinic chart review. The historical characteristics and outcome of these patients are described in Table 1.

The B-Lynch suture operation was performed on 22 patients to control intractable postpartum hemorrhage at Cesarean section not responding to uterotonic agents. In 12 instances, the B-Lynch suture was the only surgical intervention, whereas in ten it was combined with discrete vessel ligation. The procedure, either alone or combined with vessel ligation, resulted

Table 1a Biodata and clinical details of women who had B-Lynch suture for postpartum hemorrhage

Case number	*Age* (years)	*Gravidity/ parity*	*GA* (weeks)	*Reason for Cesarean section*	*Length of labor* (h)	*Estimated blood loss* (ml)	*Transfusion*
1	19	2/0	39 4/7	Arrest of dilation	17	2000	
2	26	1/0	42 3/7	Arrest of dilation	18	1600	
3	25	2/1	41 6/7	Arrest of dilation, unsuccessful VBAC	22	1500	1 unit PRBC
4	27	4/0	40 6/7	Failed induction for pre-eclampsia	15	3500	5 units PRBC, 2 units FFP
5	19	2/1	43	Elective repeat Cesarean section	0	3000	2 units PRBC
6	27	2/1	42	Elective repeat Cesarean section	0	2600	4 units PRBC, 2 units FFP
7	40	9/6	37	Elective repeat Cesarean section	0	1700	2 units PRBC
8	20	1/0	41 3/7	Arrest of dilation	20	2200	3 units PRBC
9	19	1/0	38 6/7	Arrest of dilation	12	1800	2 units PRBC
10	16	2/0	38 2/7	Arrest of dilation	7	1500	
11	27	2/1	41 5/7	Arrest of dilation, unsuccessful VBAC	18	1500	
12	20	2/0	39 2/7	Arrest of dilation	14	1100	
13	23	3/1	38 3/7	Non-reassuring fetal heart tracing, previous Cesarean section	0	1600	
14	27	2/1	40 1/7	Arrest of dilation, unsuccessful VBAC	7	2000	
15	38	3/1	40 5/7	Failed induction, unsuccessful VBAC	20	2200	
16	33	1/0	41	Failed induction	12	2300	3 units PRBC
17	32	2/1	38 3/7	Elective repeat Cesarean section	0	2000	2 units PRBC
18	28	1/0	40 2/7	Arrest of dilation	15	1500	
19	26	2/1	38 6/7	Elective repeat Cesarean section	0	2400	6 units PRBC, 1 unit FFP
20	27	1/0	40 1/7	Arrest of dilation	18	2500	
21	33	4/3	40 1/7	Arrest of descent	17	1250	
22	27	3/2	39	Prior Cesarean section × 2	0	2000	1 unit PRBC

VBAC, vaginal birth after Cesarean section; GA, gestational age; PRBC, packed red blood cells; FFP, fresh frozen plasma

Table 1b Biodata and clinical details of women who had B-Lynch suture for postpartum hemorrhage

Case number	*Uterotonic drugs given** (IV, IM, IMY)	*Postpartum hemorrhage management procedures†*
1	Oxytocin IV 70 U + IMY 10 U, methylergonovine ×2, carboprost ×5	Uterine artery ligation, ovarian vessel ligation, B-Lynch
2	Oxytocin IV + IMY 40 U, methylergonovine ×2, carboprost ×5, IV + IM	Uterine artery ligation, B-Lynch
3	Oxytocin IV 30 U + IMY 40 U, carboprost ×5, IV + IM	Uterine artery ligation, ovarian vessel ligation, B-Lynch
4	Oxytocin and carboprost	Over-sewing placental bed, uterine artery ligation, ovarian vessel ligation, B-Lynch, hysterectomy
5	Oxytocin IV 60 U, carboprost IM ×3	Uterine artery ligation, B-Lynch
6	Oxytocin IV + IMY 20 U, methylergonovine IM ×1, carboprost IM ×2	B-Lynch, hysterectomy
7	Oxytocin IV + IMY 20 U, carboprost IM ×1 + IMY ×3	Uterine artery ligation, ovarian vessel ligation, B-Lynch, hysterectomy
8	Oxytocin IV + IMY 70 U, methylergonovine IM ×4, carboprost IM ×3 + IMY ×3	Uterine artery ligation, ovarian vessel ligation, B-Lynch
9	Oxytocin IV 40 U, carboprost IM ×2	B-Lynch
10	Oxytocin IV 20 U + IMY 20 U, carboprost IM ×1 + IMY ×1	B-Lynch
11	Oxytocin IV 50 U, carboprost IM ×4	Uterine artery ligation, B-Lynch
12	Oxytocin IV 30 U + IMY 30 U, carboprost IM ×2 + IMY ×2	B-Lynch
13	Oxytocin IV 30 U + IMY 20 U, methylergonovine IM ×1, carboprost IM ×2	B-Lynch
14	Oxytocin IV + IMY 40 U, carboprost ×4, IM + IMY	B-Lynch, uterine artery ligation, hysterectomy
15	Oxytocin IV + IMY, methylergonovine IM ×1, carboprost IM ×1 + IMY ×4	B-Lynch
16	Oxytocin IV + IMY 50 U, methylergonovine IM ×2, carboprost IM ×2 + IMY ×4	B-Lynch
17	Oxytocin IV + IMY 30 U, carboprost IM ×4 + IMY ×2	B-Lynch
18	Oxytocin IV 30 U + IMY 20 U, carboprost IM ×2 + IMY ×2	B-Lynch
19	Oxytocin IV 70 U + IMY 40 U, methylergonovine IM, carboprost IM ×2 + IMY ×2,	Uterine artery ligation, B-Lynch, supracervical hysterectomy
20	Oxytocin IV, methylergonovine IM ×2, carboprost IM ×2 + IMY ×3	B-Lynch
21	Oxytocin IV + IMY 40 U, methylergonovine IM ×1, carboprost IM ×3 + IMY ×3	B-Lynch
22	Oxytocin IV, carboprost IM ×2 + IMY ×1	B-Lynch

*Methylergonovine 200 μg per dose, carboprost 250 μg per dose; IV, intravenous; IM, intramuscular; IMY, intramyometrial; †each procedure is listed in order of execution

in control of bleeding, with uterine preservation in 77% of the cases. In those instances in which the etiology of postpartum hemorrhage was uterine atony, the B-Lynch suture was successful in 85% of the cases. Hysterectomy was thus avoided in 17 of the 22 cases.

Table 1 describes the biodata and clinical details of the 22 patients. The patients' ages ranged from 16 to 40 years, with a mean age of 26.2 years. Ten patients were para 0, nine para 1, and one was para 6. ('Para' refers to parity at the start of the pregnancy, a reference point that is consistent with other case reports in the literature. These patients had delivered when hemorrhage was diagnosed.) The estimated gestational ages (EGA) ranged from 37 to 43 weeks, with an average EGA of 40.1 weeks.

All cases were delivered by Cesarean section. Uterine atony was the intraoperative clinical working diagnosis for postpartum hemorrhage in all 22 instances. All cases received intraoperative uterine compression and medical uterotonic agents. Of the 22, 11 achieved hemorrhage control with the B-Lynch suture alone. Six cases achieved control with combined B-Lynch suture and vessel ligation. The other five proceeded to hysterectomy for intractable bleeding in spite of placement of the B-Lynch suture. Two of these five were found to have focal placenta accreta on histological study. The other three had no specific pathologic finding.

Antenatal obstetric problems described in these patients included: prior Cesarean section (11 cases), arrest disorder of labor (12 cases), oxytocin labor induction/augmentation (11 cases), chorioamnionitis (eight cases), pre-eclampsia (five cases), pre-operative magnesium sulfate (four cases), macrosomia (seven cases), and gestational diabetes (two cases). Obviously, many patients had more than one problem that preceded hemorrhage.

All cases received intraoperative uterine compression and medical uterotonic agents (oxytocin, methylergonovine, 15-methyl prostaglandin $F_{2\alpha}$[3] (carboprost)). Twelve patients did not receive methylergonovine, seven of whom had hypertensive disease.

Three surgical approaches were noted when the B-Lynch suture was used:

(1) B-Lynch technique was the only uterine-preserving hemostatic surgical procedure performed (12 cases);

(2) Uterine artery ligation (nine cases, five with additional ovarian vessel ligation) was performed first, followed by B-Lynch technique; and

(3) B-Lynch suture was performed first, followed by uterine artery ligation.

In the 12 patients where the B-Lynch was the only surgical procedure performed to achieve hemostasis, 11 resulted in hemorrhage control with uterine preservation. The estimated blood loss ranged from 1100 to 2600 ml. Five patients received transfusion of packed red blood cells. Two patients developed dilutional coagulopathy. Only one B-Lynch suture case required hysterectomy for intractable uterine hemorrhage. That patient, who had undergone an elective repeat Cesarean section at term, developed severe uterine atony, unresponsive to uterine manual massage and uterotonics. Despite placement of a B-Lynch suture, brisk bleeding continued, and the patient developed dilutional coagulopathy intraoperatively. In face of continued life-threatening hemorrhage and the patient's preoperative desire and consent for permanent sterilization, the surgeon proceeded to hysterectomy for intractable hemorrhage. The patient received 4 units packed red blood cells and 2 units fresh frozen plasma (FFP), and had an uncomplicated postoperative course. Histological study did not reveal placenta accreta.

Nine patients first underwent uterine artery ligation (five with ovarian vessel ligation) followed by B-Lynch technique. Six of these nine cases resulted in hemorrhage control with uterine preservation. The estimated blood loss in these cases ranged from 1500 to 3500 ml. Six patients received transfusion of packed red blood cells. Two cases of coagulopathy required FFP transfusion.

In 13 instances, the B-Lynch technique was the surgical procedure applied first. Among these, one case was followed by uterine artery ligation to achieve hemorrhage control, and one proceeded to hysterectomy, as previously noted. The cases in which the surgeons chose to apply

first the B-Lynch technique occurred in the latter years of the study (after 1999). This may reflect the surgeons' preceding experiences of successful B-Lynch cases, thus fostering greater willingness and less suspicion for the brace suture application. A total of seven surgeons and approximately 20 residents managed these cases.

Of the 22 cases, 17 resulted in hemorrhage control with uterine preservation. Among the five B-Lynch cases that proceeded to hysterectomy, two were noted to have focal placenta accreta. Seven patients with uterine preservation developed postoperative endometritis. Five of these cases had preceding chorioamnionitis during labor. There were no cases of postoperative pyometrium[4]. None of the B-Lynch cases required readmission for recurrent bleeding.

Twelve of 17 B-Lynch patients with uterine preservation were contacted for follow-up 1 month to 7 years after the operation. Five patients could not be reached due to changes in address and phone number and, therefore, were lost to follow-up. Nine patients were on reversible contraception. One patient underwent laparoscopic tubal sterilization 3 months after B-Lynch procedure. The uterus was described as normal in the laparoscopy operative note.

One patient is presently pregnant at 28 weeks' gestation, with an uncomplicated course. Conception occurred 1 year after the B-Lynch procedure.

Two patients delivered live births after receiving the B-Lynch procedure. One patient had a term vaginal delivery (vaginal birth after Cesarean section), 3.5 years after the B-Lynch procedure, resulting in a liveborn female infant, Apgar scores 9 and 9. A second patient underwent a repeat Cesarean section, 2 years after B-Lynch procedure, at 24 5/7 weeks' gestation for preterm premature spontaneous rupture of membranes and non-reassuring fetal heart rate tracing. No uterine anomalies or marks from the prior B-Lynch procedure were noted intraoperatively.

When the B-Lynch procedure was used alone, it was effective in 92% of cases of postpartum hemorrhage in our institution. When used in combination with vessel ligation, it was effective in 60% of cases.

COMMENT

In 1997, Christopher B-Lynch introduced a uterine compression suture for the control of postpartum hemorrhage after Cesarean section[2]. The B-Lynch technique or 'brace suture' is performed at laparotomy, with a hysterotomy incision in the lower uterine segment. Of the five cases presented by B-Lynch, three were delivered by Cesarean section, and two by the vaginal route. The patients who delivered vaginally underwent laparotomy and hysterotomy for B-Lynch suture placement. The etiology of postpartum hemorrhage in the original B-Lynch series was variable, including uterine atony, placenta previa and coagulopathy.

In our case series, all 22 cases involved placement of B-Lynch suture at Cesarean section, and, therefore, the laparotomy and hysterotomy prerequisites of suture placement were already in place. All 22 of our cases had the intraoperative diagnosis of uterine atony (two cases also had diagnosis of placenta accreta).

Since the B-Lynch technique was introduced, several case reports and small case series, ranging from one to seven cases, have been published[5–19]. These publications are summarized in Table 2. Of the 43 cases reported since B-Lynch's report, 35 were delivered by Cesarean section, six were delivered vaginally, and two were without specification of delivery route. Uterine atony was the etiology in 36 of these 43 cases. Placenta accreta and placenta previa were the causes of postpartum hemorrhage in four instances[6,8,12,15]. Lower uterine segment bleeding was reported in two cases[16]. B-Lynch brace suture prophylactic application was reported in one case of triplet pregnancy in a Jehovah's Witness[10]. One case of B-Lynch suture placement for uterine atony in the second trimester of pregnancy was also reported, with suture placement after uterine vacuum curettage for intrauterine fetal demise[18].

The cumulative 'success rate' (number of cases achieving control of postpartum hemorrhage with uterine preservation/total number of cases) is 98%. By combining the literature cases with our series, 70 cases are identified with a 'success rate' of 91%.

Table 2 B-Lynch suture: literature review

Author	*Date*	*Number of cases*	*'Success' rate**	*PPH etiology*		*Delivery route*	
B-Lynch *et al.*	1997	5	5/5	uterine atony	1	Cesarean	3
				placenta previa	1	vaginal	2
				DIC	2		
				unspecified	1		
Ferguson *et al.*	2000	2	2/2	uterine atony	2	Cesarean	2
Dacus *et al.*	2000	4	4/4	uterine atony	3	Cesarean	3
				placenta accreta	1	vaginal	1
Vangsgaard	2000	1	1/1	uterine atony	1	Cesarean	1
Hayman *et al.*	2002	3**	3/3	uterine atony	2	Cesarean	2
				placenta accreta	1	vaginal	1
Wergeland *et al.*	2002	5	5/5	uterine atony	5	Cesarean	2
						vaginal	1
						not stated	2
Kalu *et al.*	2002	1	1/1	prophylactic	1	Cesarean	1
Danso *et al.*	2002	1†	1/1	uterine atony	1	Cesarean	1
Mazhar *et al.*	2003	2	2/2	uterine atony	1	Cesarean	2
				placenta previa	1		
Smith *et al.*	2003	7	6/7	uterine atony	7	Cesarean	7
Pal *et al.*	2003	6	6/6	uterine atony	6	Cesarean	6
Chaudhary *et al.*	2003	1	1/1	placenta increta	1	Cesarean	1
Holtsema *et al.*	2004	7	7/7	uterine atony	5	Cesarean	6
				lower uterine segment bleeding	2	vaginal	1
Grotegut *et al.*	2004	1	1/1	uterine atony	1	Cesarean	1
Hillaby *et al.*	2004	1	1/1	uterine atony	1	vaginal (curettage for fetal demise 2nd trimester)	1
Malibary	2004	1**	1/1	uterine atony	1	vaginal	1

*Number of cases achieving hemorrhage control with uterine preservation/total number of cases; **modified B-Lynch; †B-Lynch suture combined with intrauterine balloon catheter; DIC, dilatation & curettage

Eight live births are reported after B-Lynch. Four cases were reported by El-Hamamy and B-Lynch[20]. Holtsema and associates presented two cases of live births delivered by Cesarean section after B-Lynch[16]. The seventh and eighth cases of live births after B-Lynch brace suture are within the current series. Additionally, an uncomplicated 28-week gestation after B-Lynch is being followed in our case series.

Consistent with the original B-Lynch study, subsequently reported cases involved reopening the Cesarean section hysterotomy wound for brace suture placement. Pal and associates reported cases where the hysterotomy was left open until hemorrhage control was secured after placing the B-Lynch suture[14]. The Cesarean hysterotomy management in our series varied, including initial closure and reopening for brace suture placement, partial closure until brace suture placement, or closure after brace suture placement.

In 2002, Hayman introduced a 'modified' B-Lynch suture, whereby brace sutures are placed without hysterotomy incision[8]. Hayman described placing brace sutures in a patient who delivered vaginally and subsequently underwent laparotomy for postpartum hemorrhage. He describes an intact uterus with the lower segment relatively well contracted. Using four 1-vicryl sutures and passing the needle from

front to back in line where a lower segment incision would have been, uterine compression was achieved with resultant control of postpartum hemorrhage.

The B-Lynch technique appears to be a safe and efficacious procedure. The cases of postoperative endometritis responded to antibiotic treatment, and there were no injuries to bladder, ureters, broad ligament, or pelvic side-wall vessels. Patients with long-term follow-up demonstrated resumption of menses and normal reproductive health practices.

In 2004, Grotegut and associates reported one case of erosion of a B-Lynch suture through the uterine wall[17]. A 19-year-old primigravida underwent successful B-Lynch suture placement at Cesarean section, using No. 0 Maxon (US Surgical, Norwalk, Connecticut, USA). At 6 weeks postpartum, the suture was noted to be protruding through the cervical os and was removed without difficulty. Sonohysterography performed 6 months after the operation showed a small defect in the anterior wall of the lower uterine segment. The authors commented that the effect of the erosion on future fertility and labor is unknown.

Danso and Reginald[11] presented one case report of B-Lynch suture technique used in combination with intrauterine balloon catheter for control of postpartum hemorrhage. A 38-year-old primigravida underwent Cesarean section at 41 weeks and 3 days gestation for failure to progress. Uterine atony was encountered. Uterine massage, oxytocin and carboprost uterotonics, and B-Lynch brace suture all were applied. Although significant reduction in bleeding was noted after these measures, moderate blood loss continued from the vagina. Through the vagina, a three-way prostatic balloon catheter was inserted into the uterus and filled with 70 ml of water, resulting in tamponade. Bleeding was reported to have stopped immediately.

The B-Lynch suture cases at White Memorial Medical Center present the largest series to date using this procedure for uterine preservation. Reproductive outcome is also reported. Theoretical limitations of this case series study include the small sample size and absence of a controlled, randomized design. However, because postpartum hemorrhage cannot be anticipated and often occurs under urgent or emergent life-threatening situations, controlling for variables and randomization may be exceedingly difficult to implement and of highly questionable ethical value.

Within the limitation of only having case reports and case series in the literature and the unlikelihood of ever having data from a randomized trial, the authors propose an algorithm (Figure 1) for the use of the B-Lynch technique at Cesarean section, where the prerequisites of laparotomy and hysterotomy are part of the delivery process.

USING THE WMMC ALGORITHM

Given that 59 of 70 cases (84%) in the literature were for postpartum hemorrhage due to uterine atony, this diagnosis serves as a template for the B-Lynch procedure. After proceeding with uterine massage, close the hysterotomy to minimize blood loss from dilated myometrial vessels. Administer medical uterotonics: oxytocin, methyl ergonovine in the non-hypertensive, carboprost, and misoprostol[21]. Although oxytocin is often given as first-line prophylaxis at placental delivery, there is no evidence to support any specific sequence of use. If hemorrhage persists, continue bimanual compression. As described in the original article, decreased bleeding with compression serves as an assessment tool for the potential success of the B-Lynch technique[2]. If there is decreased bleeding with compression, proceed with the B-Lynch suture.

There is no evidence that either uterine artery ligation or B-Lynch is more effective or safer than the other. However, in the presence of uterine atony, the authors suggest that it makes clinical sense to proceed with surgical uterine compression. If the standard B-Lynch technique is used, the hysterotomy is reopened. If the hysterotomy is left intact, the modified B-Lynch by Hayman may be utilized[8].

If hemorrhage persists, after manual massage, multiple uterotonic agents and B-Lynch suture, proceed with step-wise uterine devascularization with uterine artery ligation and ovarian vessel ligation[22]. If hemorrhage remains brisk after these interventions,

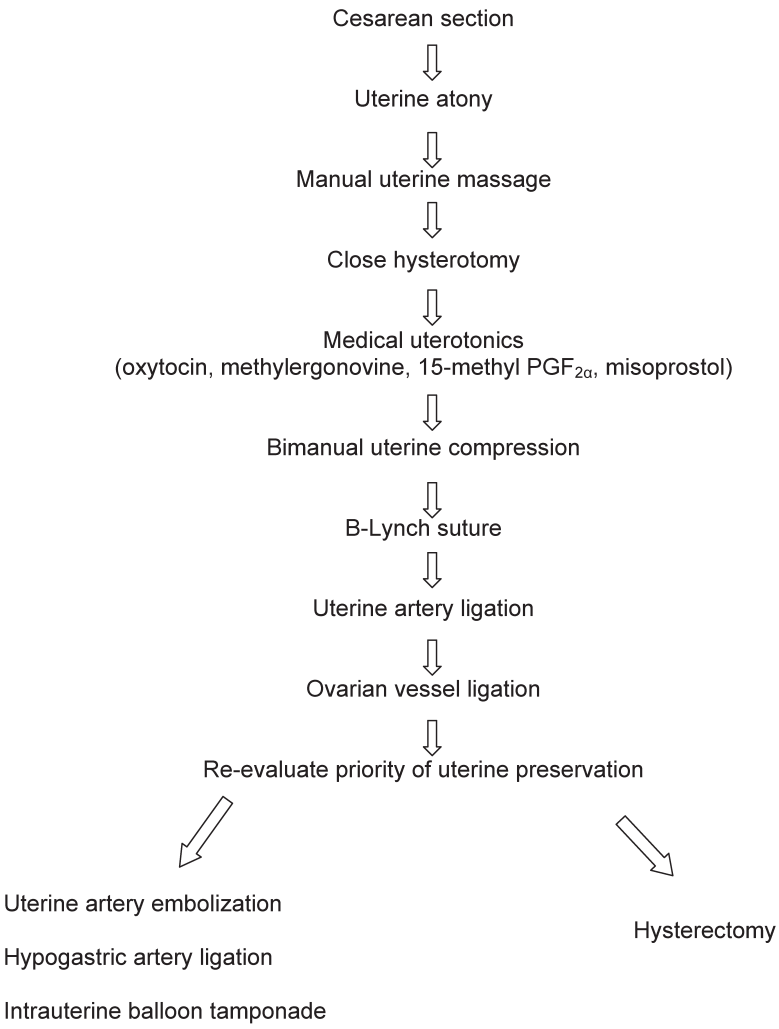

Figure 1 Postpartum hemorrhage due to uterine atony: management at Cesarean section

hysterectomy must be considered. Generally, the above measures are performed over time, with varying intervals between uterotonic agents and surgical procedures. As blood loss accumulates, continued consideration must be given to the patient's hemodynamic stability, presence of coagulopathy, and the potential for further compromise of the patient's already critical condition with continued delay rather than proceeding to hysterectomy. This is especially true if blood replacement supplies are diminishing or non-existent. If uterine preservation remains a high priority, assess the patient's stability for selective artery embolization if such facilities are available, hypogastric artery ligation, or intrauterine balloon tamponade.

Hypogastric artery ligation has a reported success rate of 50–60%, but carries with it the associated risks of retroperitoneal surgery[23]. Moreover, the technique is not familiar to all obstetric surgeons, and the use of hypogastric artery ligation precludes angiographic embolization as an option. Selective artery embolization has a reported success rate of 85–95%, but requires immediate proximity of an equipped invasive radiology set-up and experienced personnel[24]. Intrauterine balloon tamponade is dependent upon availability of the appropriate device[11]. At this point, the choice of procedure for control of postpartum hemorrhage in the algorithm is a judgment best decided by the treating physician.

CONCLUSION

In the presence of postpartum uterine hemorrhage, rapid diagnosis and intervention are paramount to effective treatment. When preservation of the uterus is desired, the surgeon must be knowledgeable in those techniques that will maximize this eventuality. The B-Lynch suture is one of a number of new options available to the obstetrician. It is an alternative uterus-preserving surgical procedure that is effective in controlling postpartum hemorrhage from uterine atony. In our experience, the B-Lynch technique is technically simple, easy to learn, can be performed quickly, and may be used in combination with traditional uterine preserving procedures.

Recent graduates of the White Memorial Medical Center's Obstetrics and Gynecology Residency Training Program, trained in the B-Lynch suture technique, continue to utilize the brace suture for management of postpartum hemorrhage in their practices. Their skills and knowledge are testimony to the impact of physicians' commitment to scholarly activity. Through discovery, dissemination and application of new approaches and new techniques, the care of the patient is continually improved and optimized.

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