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PEDICLE-AND-BED HYDRODISSECTION IN DIFFICULT LAPAROSCOPIC CHOLECYSTECTOMY

By
Mohamed El-Sherif El-Sarky.
Department of Surgery, Faculty of Medicine,
Cairo University, Egypt

Intense acute inflammatory reaction, as in acute cholecystitis, and extensive vascularity and bleeding, as in liver cirrhosis, portal hypertension and coagulopathy, present distressing difficulties during laparoscopic cholecystectomy. In this work, hydrodissection was employed to overcome these difficulties. Injection of saline under pressure is done into tissue planes at selected points creating aqueous dissection zones. At the pedicle, inflation of tissue planes makes identification and dissection of structures more feasible, safer, and less bloody. At the bed, the aqueous zone at the cholecysto-hepatic boundary results in full separation from the liver with faster dissection, easier hemostasis and lesser chance for wall perforation. This study compares 37 patients (group A) who had this technique with 22 others who did not, though they had its indications (group B). Total operation time was shorter in group A (58.2±12.7 versus 74.1±23.5 minutes) and so were pedicle dissection time (11.4±5.5 versus 19.7±13.8 minutes) and bed workup time (7.2±2.2 versus 14.0±3.4 minutes). Group A patients had a lower incidence of conversion (0/37 versus 3/22), lower need for blood transfusion (0/37 versus 2/22), lower incidence of gallbladder perforation and stone spillage (1/37 versus 4/22) and lower need for a drain (1/37 versus 8/22). Both groups had comparable average duration of stay in hospital (2.7±1.3 versus 2.5±1.9 days) but group A patients returned faster to full activity (5.7±4.6 versus 9.8±7.6 days). Results of this work encourage the use of this method in difficult laparoscopic cholecystectomy.

Key words : Difficult cholecystectomy – hydrodissection – gallbladder pedicle – gallbladder bed

INTRODUCTION

Compared with those of open surgery, which are considered established, the essential skills, maneuvering techniques and operating tactics in laparoscopic surgery are still in evolution. The laparoscopic surgeon may recognize at times that his/her technique can't match the difficulties encountered in the field. The end-result in these challenging situations may be: a very lengthy procedure, an increased risk of complications, or conversion to open surgery. Difficult laparoscopic cholecystectomy (DLC) presents one of these challenging situations.

The definition of DLC is not settled. Several parameters have been employed for this definition, including: prolonged operating time [1-3], surgeon's own opinion [4], unforced conversion to open surgery, i.e. without complications[1,4], and observed specific difficulties which include: adhesions in Calot's triangle[3,5], factors which predispose to bleeding as cirrhosis and increased vascularity [6-8], and amount of blood loss [1].

Hydrodissection is the principle of separating tissue planes by employing crystalloid solution. It has been traditionally employed in open surgery to facilitate separation of the gallbladder from its bed. Recently, it was

employed in laparoscopic cholecystectomy for the same purpose [9].

In this work, hydrodissection was extensively used in DLC to facilitate dissection of the pedicle and bed. Its basic effects were explored and defined and its impact on the outcome was analyzed.

PATIENTS AND METHODS

This study compares two groups of patients who had laparoscopic cholecystectomy and one of the suggested prime indications for the technique. Group A (37 patients) had laparoscopic cholecystectomy with hydrodissection while group B (22 patients) had standard laparoscopic cholecystectomy.

The indications for hydrodissection were suggested to be: 1) acute cholecystitis with extensive inflammatory reaction, 2) extensive vascularity and bleeding as in: portal hypertension, liver cirrhosis and coagulopathy, and 3) unfavorable anatomy as in intra-hepatic gallbladder.

Method of hydrodissection

Basically, the procedure entails injection of cold saline under pressure into certain tissue planes at selected points. A laparoscopic cyst aspiration needle is employed, connected to a large (50 ml) syringe. The process of injection, in both the pedicle and the bed regions, is done in 4 steps. First, the needle is advanced towards the selected initial injection point, via one port, strictly under vision by the operating telescope. Second, the tip is introduced into the target tissue plane at selected points, slowly, tangentially and in steps (turning the tip around may prove useful in controlling advancement). Third, pressure is repeatedly applied to the syringe till the proper injection plane is reached as confirmed by 2 signs: 1) A visible initiation sign, and 2) marked tissue resistance to injection. The visible sign varies according to the site (the bubble sign in the pedicle and the halo sign in the bed). Fourth, injection of a large volume of saline follows till the end point is reached (according to desired degree of tissue inflation).

In hydrodissection of the pedicle, initial injection is done at the lowest identifiable point in the region of gallbladder neck. The tip of the needle is directed towards Calot's triangle. The initiation sign is called the "***bubble sign"*** which is appearance of a semi-translucent bubble due to tissue inflation, (Fig.1). Easy flow (no resistance) of fluid without appearance of the bubble means injection into an open space. This requires retrying injection at a new point. The end point is reached when the region of Calot's triangle is observed to be ballooned, (Fig.2) .

In Hydrodissection of the bed, the initial injection point is selected in the gallbladder wall close to the hepato-cholecystic boundary, at the edge of the gallbladder fossa, on the left side. The initiation sign is called the "***halo sign"***. It is the sudden appearance of a halo around the site of injection, (Fig..3). Lack of resistance or absence of this sign usually means intraluminal injection. This requires retrying injection at a new point. Injection is repeated at 2 or 3 points on the same side then on the other side of the gallbladder. More frequently, the endpoint is considered when a visible semi-translucent aqueous zone (2 cm thick) develops separating the gallbladder from the liver. In deep and intrahepatic gallbladder, injection continues till the whole gallbladder is elevated above the liver surface, (Fig..4). Dissection is then initiated midway between the gall bladder and the liver, within this aqueous zone, (Fig..5). A thick edematous tissue layer is left on the bed after removal of the gallbladder, (Fig. 6).

Assessment of results

The studied two groups of patients were compared in operative details and postoperative recovery. Review of videotapes allowed observing certain events, difficulties and complications (gallbladder perforation, stone spillage, major bleeding from the liver, injuries, use of a drain, and conversion). Digital time analysis allowed measurement of major intervals (total operation time, pedicle dissection time and bed workup time). Other events were retrieved from patients' files as: blood transfusion, early postoperative recovery, postoperative complications, drain time, duration of stay in hospital, and complications. Return to full activity was assessed by communicating with the patient in the follow-up period.

RESULTS

The two groups of patients were comparable in age and sex (Table I). Of the suggested indications for hydrodissection, the most frequent one in both groups was acute cholecystitis, (Table II).

As shown in (Table III), all conversions to open surgery (3 cases) were in group B ($p < 0.10$) and so were all blood transfusions (2 patients, not statistically significant). Perforation of gallbladder during the procedure was more frequent in group B (not statistically significant). Requiring a drain was also more frequent in group B ($p< 0.005$).

Time analysis (Table IV) revealed that all the measured intervals were observably shorter in A group, including: pedicle dissection time ($p < 0.005$) bed workup time ($p < 0.001$), and total operation time ($p < 0.005$).

The duration of stay in hospital was comparable in the two studied groups of patients but return to full activity was earlier in group A ($p < 0.025$). No mortality occurred in the studied patients. The incidence of general complications was comparable in both groups, (Table V)

Item	*A*	*B*
Number	37	22
Age (years)	47.4±18.1	43.3±13.4
Sex		
- Male	6	5
- Female	31	17

Table I: ***Patients of the two studied groups***

Indications	*A*	*B*
Intense adhesions at Calot's triangle	3 (8.1%)	2 (9.1%)
Intrahepatic gallbladder	1 (2.7%)	0
Coagulopathy	2 (5.4%)	1 (4.5%)
Portal hypertension	5 (13.5%)	2 (9.1%)
Acute cholecystitis	17 (46%)	11 (50%)
Liver cirrhosis	9 (24.3%)	6 (27%)

Table II: ***Indications for hydrodissection in the two groups.***

Parameter	*A*	*B*
Conversion	0/37 (0%)	3/22 (13.6%)
Blood transfusion	0/37 (0%)	2/22 (9.1%)
Perforation of gallbladder	1/37 (2.7%)	4/22 (18.2%)
Drain	1/37 (2.7%)	8/22 (36.4%)
Stay in hospital (days)	2.7±1.3	2.5±1.9
Return to full activity(days)	5.7±4.6	9.8±7.6

Table III: ***Operative events and postoperative recovery in the two studied groups***

Time parameter	*B*	*A*
Total time	74.1±23.5	58.2±12.7
Pedicle dissection time Bed	19.7±13.8	11.4±5.5
workup time	14±3.4	7.2±2.2

Table IV: ***Time interval analysis in the two groups of patients***

Item	*A*	*B*
Mortality	0	0
General complications	5	4
Bile duct injuries	0	0
Local sepsis	0	1
Postoperative bleeding	0	1
Port site infection	0	2

Table V*: Mortality and morbidity in the two groups of patients*

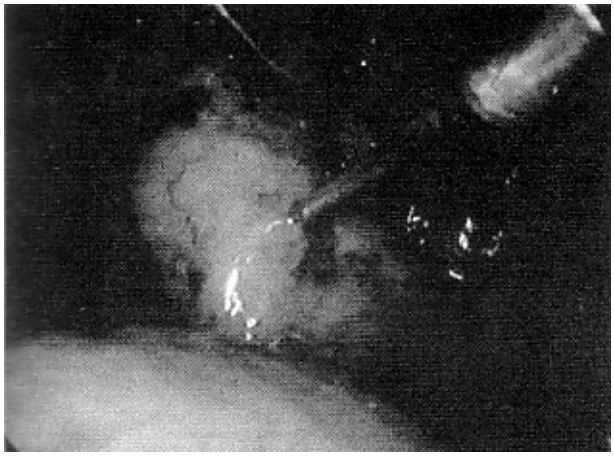

Fig. 1 : Initiation of Pedicle injection, "bubble sign".

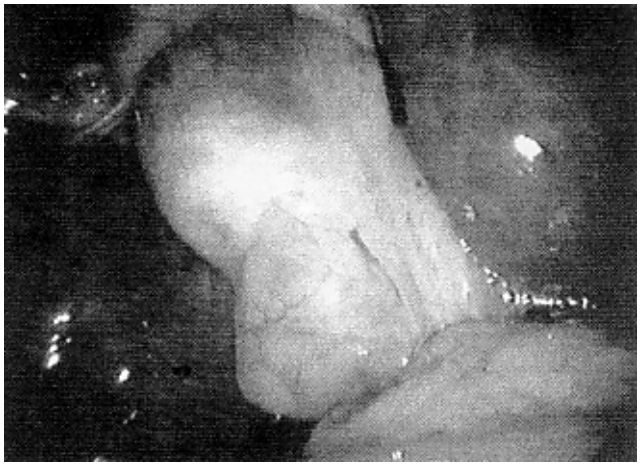

Fig. 2 : Endpoint in pedicle injection (ballooning)

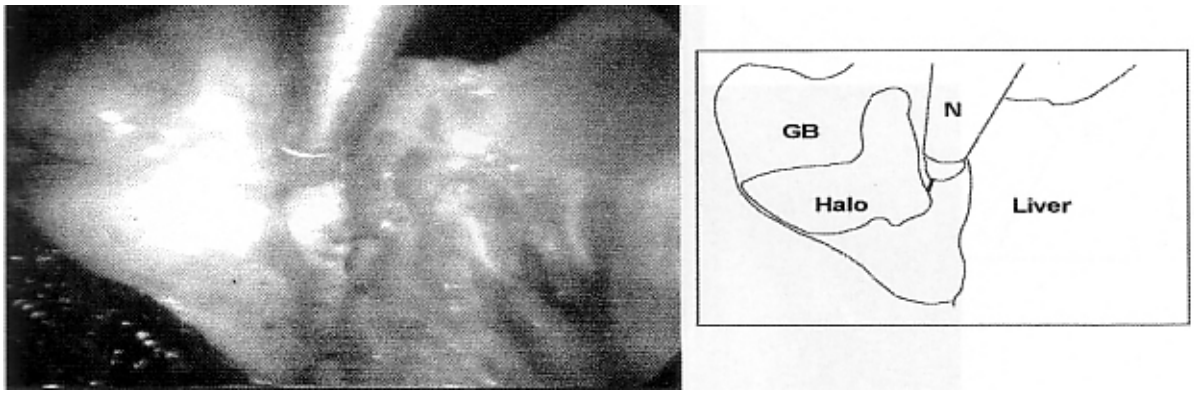

Fig. 3: Initiation of bed injection in cirrhosis,the "halo sign".

(N: needle , GB: gallbladder).

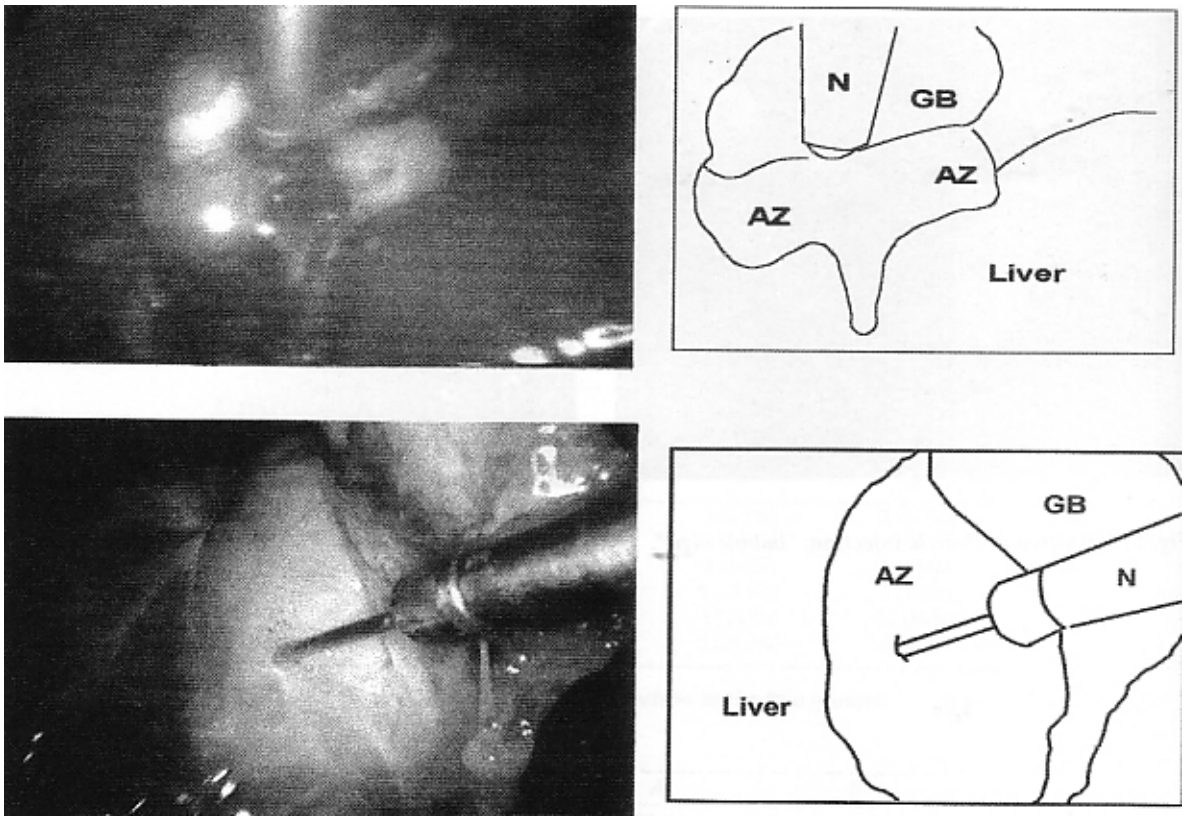

Fig. 4: Hydro-elevation in 2 cases: marked elevation of the whole gallbladder above the surface of the liver by creation of a huge aqueous zone . (N: needle , GB: gallbladder , AZ: aqueous zone)..

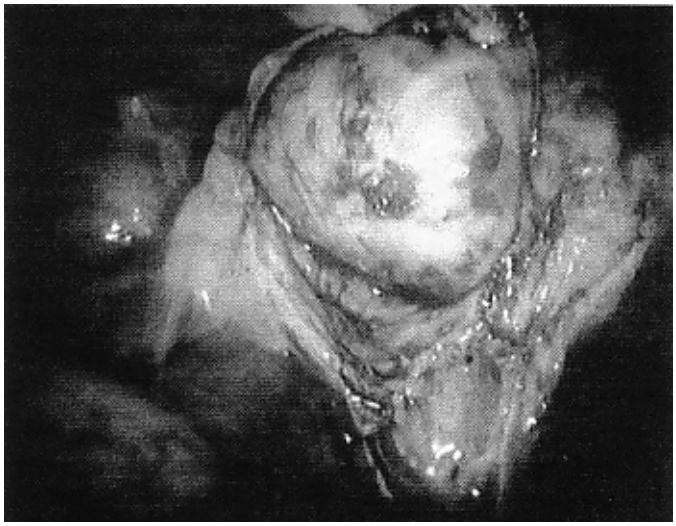

Fig. 5 : Dissection within the AZ in a case of acute cholecystitis.

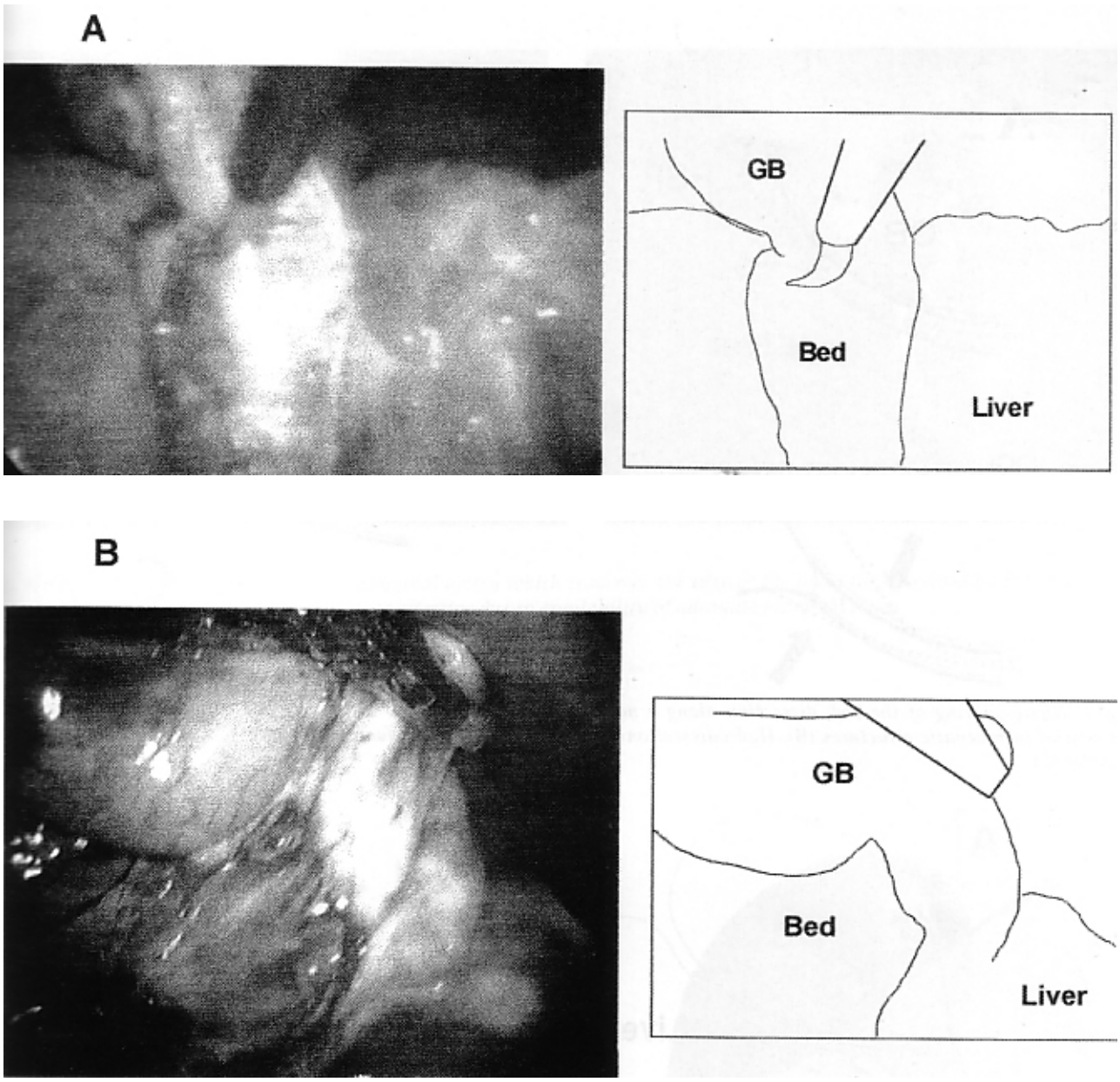

Fig. 6: Bed dissection leaving a thick edematous tissue layer on the bed with available length of crossing structures which allows their identification and control (A : in cirrhosis, B : in coagulopathy).

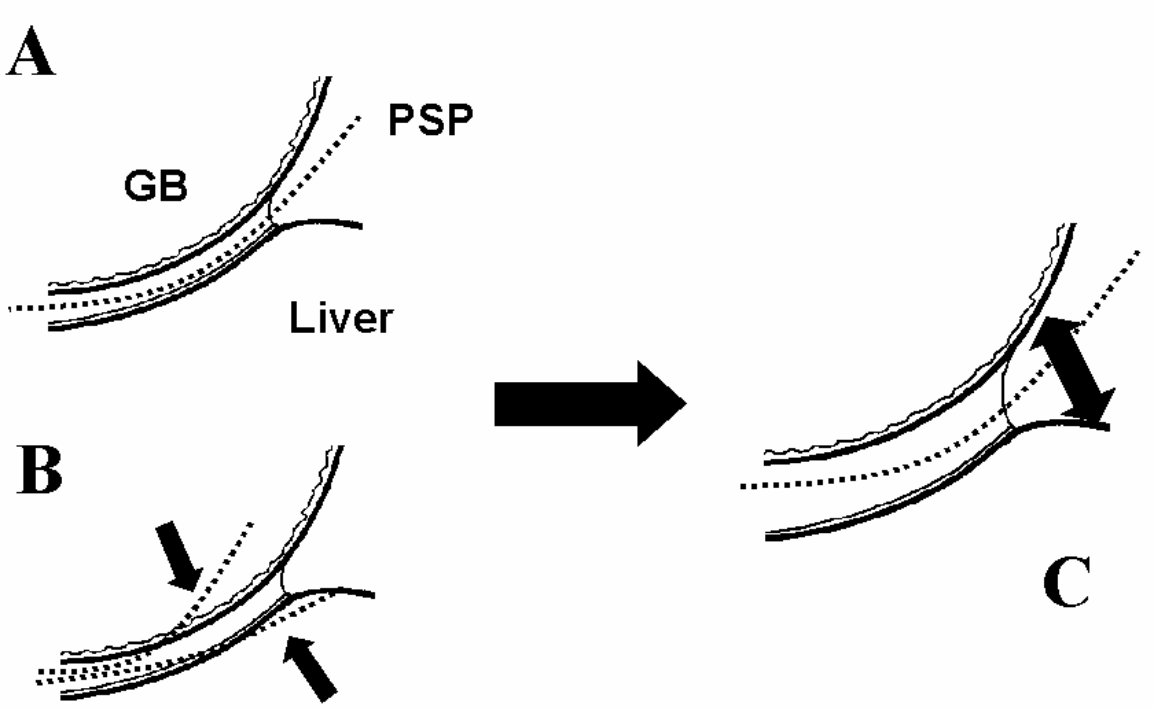

Fig. 7: Hydro-spacing of the bed: dissection along a narrow PSP predisposes to injuries to the gallbladder, the liver and superficial intrahepatic structures (B). Hydrodissection augments the PSP. This facilitates dissection and reduces potential injuries (C)

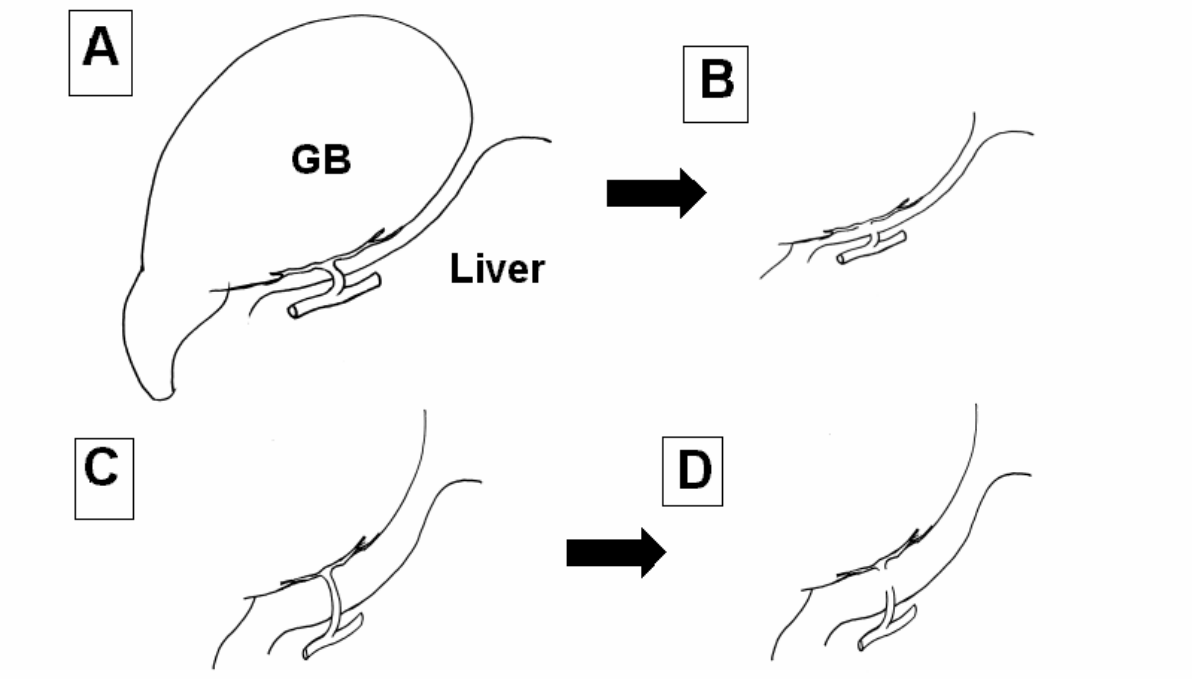

Fig. 8: Hydro-elongation: A) The narrow PSP contains short segments of crossing structures. B) These segments are difficult to identify and their injury leaves short stumps which are difficult to control. C) Hydrodissection causes stretching of crossing structures leading to longer visible segments. D) Stretched structures are easier to identify and control.

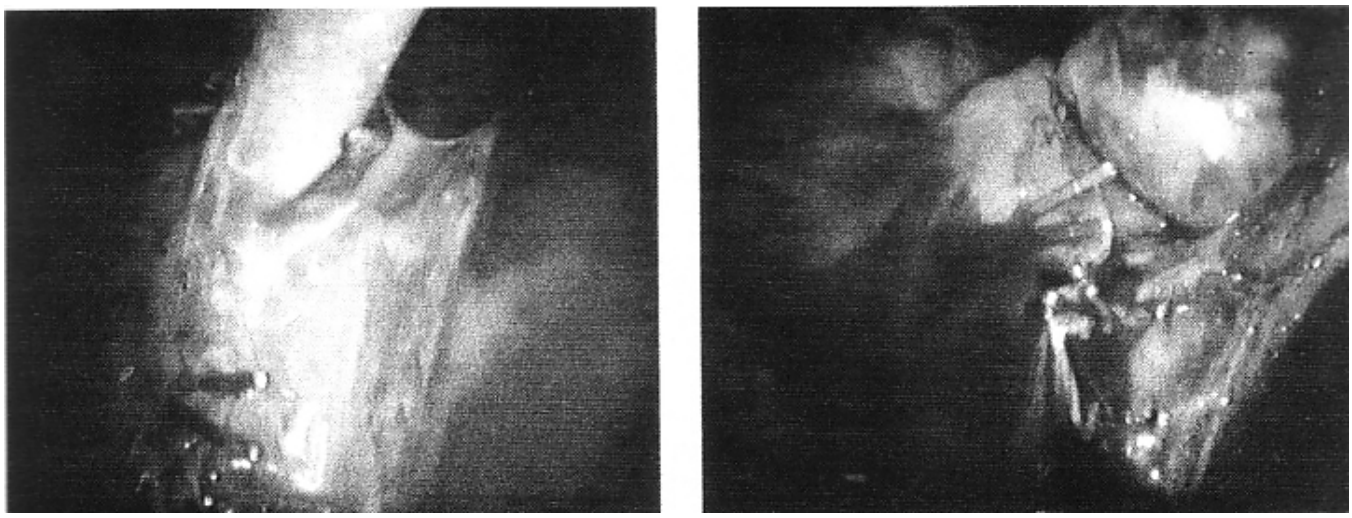

Fig. 9: Controlling bleeding from a large marginal artery which traverses the edge of the fossa (as described by Bergamaschi and Ignjatovic) in 2 cases: applying clips was effective due to availability of adequate marginal tissue.

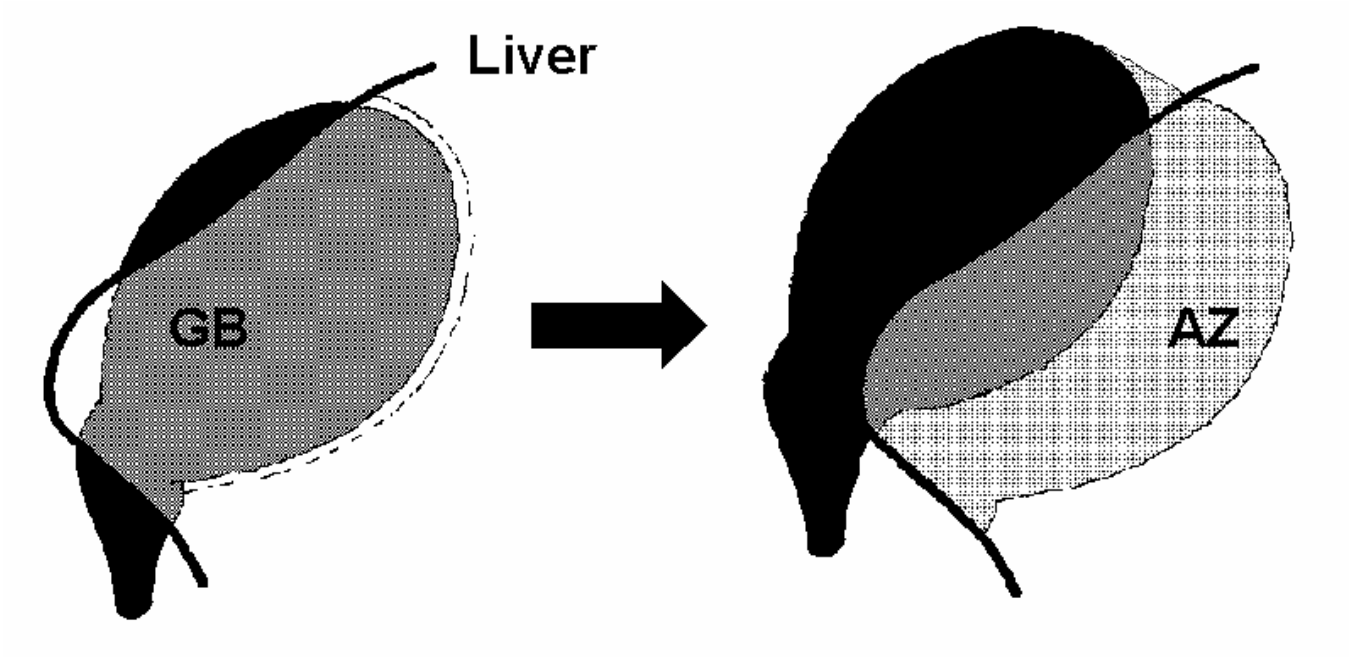

Fig.10: Hydro-elevation: Deeply seated gallbladder is made accessible by maximal injection in the bed region (AZ: aqueous zone).

DISCUSSION

Difficult laparoscopic cholecystectomy (DLC) is a distressing situation that may defy standard technique, known tactics and common skills. In response to this situation, the surgeon may resort to any of 3 solutions: conversion to open surgery, modifying the procedure in magnitude or approach, or employing a method that enhances dissection and maneuvers.

Conversion to open surgery in DLC was recommended by some surgeons to avoid complications[10]. Technical difficulties are the leading cause for conversion in laparoscopic cholecystectomy. They were reported to be the cause of 68 to 74% of all conversions[5,11,12]. Complications and equipment failure are less frequently the causes for conversion.

The second solution in DLC is to modify the procedure. Standard cholecystectomy could be modified in approach by resorting to the "fundus-first" method to avoid difficulties in the region of the pedicle. It has also been modified in magnitude by resorting to subtotal cholecystectomy. Both procedures were practiced in open surgery and were recently advocated for laparoscopic cholecystectomy.

In the fundus-first laparoscopic cholecystectomy, the procedure may start by separation of the gallbladder from the bed before any pedicle dissection[13,14]. Alternatively, division of the cystic artery and clipping of the cystic duct, without division, may be done first[15]. As the operation proceeds from the fundus towards the neck, the cystic duct and artery become more easily identified after full separation of the gallbladder from its bed.

Subtotal cholecystectomy was recently reported as a laparoscopic procedure [8,16,17] years after its practice in open cholecystectomy[18]. In this procedure, dissection of the bed is avoided by leaving the posterior (hepatic) wall of the gallbladder intact. Identification of the cystic duct becomes easier with an open gallbladder and its clipping or closure with an endo-loop becomes safer.

The third solution for DLC is to employ methods that enhance the feasibility of dissection in difficult areas. Suggested methods included using ultrasonic dissector[19,20] or aspirator[21,22]. The current study employs a simple method which is hydrodissection. Hydrodissection has been used traditionally in open cholecystectomy and was recently applied in laparoscopic cholecystectomy [9]. In this work, its value in difficult situations, its basic effects, and its impact on the procedure and the outcome were studied.

Cholecystectomy consists basically of 2 parts: pedicle dissection and bed dissection. Difficulties can be encountered in either or both these areas. Difficulties in pedicle dissection are frequently due to intense inflammatory reaction, dense adhesions or excessive vascularity in Calot's triangle. Pedicle difficulties predispose to duct injuries and bleeding. They were reported to be responsible for 70% of conversions in DLC[23].

In addressing pedicle difficulties, hydrodissection produces 2 useful basic effects: hydro-spacing and hydro-priming. Hydro-spacing means augmentation of the volume of tissue and creation of aqueous dissection zones due to inflation by the injected fluid. These aqueous zones have protective effects. In the region of the pedicle, they increase distances between closely packed pedicle structures which leads to more feasible identification, dissection and manipulation of these structures. In the region of the bed, hydro-spacing results in a different effect which is discussed below.

Hydro-priming means selective modification of the structure and density of tissues in a way that augments their differences. Pressurized injection of fluid makes areolar tissues looser and less dense due to incorporation of injected fluid and dispersion of their structural elements. Accordingly, they require minimal blunt dissection to clear. On the other hand, tough indurated tissues are not markedly altered by injection. They become more distinct as sturdy bands which need to be specifically addressed during dissection by aggressive dissection tools (diathermy coagulation and sharp dissection). The hydro-priming enhanced tissue distinction results in discriminate, targeted, and limited use of these aggressive dissection tools which enhances precision in dissection and reduces potential injury to bile ducts and vessels.

These two effects of hydrodissection are particularly useful in 2 situations. The first is difficult identification of anatomy due to either acute inflammation (when adherent inflammatory tissue obscures pedicle structures) or encountered anomalies (when dissection has to be cautious, extensive and deep to identify structures). The other situation is expected bleeding due excess vascularity, as in portal hypertension, or coagulopathy.

Three technical difficulties may be associated with bed dissection. The first is keeping the process of gallbladder separation within the appropriate plane. The second is identification and control of the crossing structures that traverse the bed and connect the gallbladder with the liver (arteries, veins and bile ducts). The third is manipulation and dissection of a gallbladder which is intrahepatic or deeply seated (e.g. in a large fatty liver).

The intact gallbladder bed is a strong fibromembranous lining which is adherent to the liver surface. It is rich in

collagenous, elastic, and reticular fibers and contains numerous small blood vessels and bile ductules[24]. This gallbladder bed membrane (GBM) is better left intact during cholecystectomy so that separation of the gallbladder from the liver is performed within a plane which is superficial to it, i.e. on gallbladder side. This is the proper separation plane, PSP.

The PSP is less likely to be maintained during dissection when it is ill-defined, narrow or sclerotic. It becomes ill-defined in acute cholecystitis as the inflammatory process may extend to involve tissues on both sides of the GBM obscuring the PSP. In severe cases, the GBM may be abolished and the inflammatory process extends towards the liver resulting in an intrahepatic pyogenic abscess which is continuous with the inflamed gallbladder [25,26].

Violation of the PSP may occur inwards towards the liver. This may result in injuries to the liver parenchyma or superficial intrahepatic structures. Outward violation, towards the gallbladder wall, may cause its perforation and spillage of bile and stones.

Parenchymal liver injury during gallbladder separation is frequently produced by sharp dissection or electrocoagulation. It may cause profuse bleeding which is difficult to control by cauterization [27]. In addition, some superficial intrahepatic structures, that occasionally lie beneath the bed, may be injured as well. One example is a large tributary of the middle hepatic vein that was described in 10% of people[28]. Bleeding from this vessel was reported to be serious and result in a conversion rate of 25% [28]. Superficial intrahepatic bile ducts may also be injured, commonly in association with coagulation-related parenchymal necrosis [27]. They present by bile leakage [27] extrahepatic biloma, or intrahepatic biloma [29,30].

Hydro-spacing, described above in pedicle dissection, plays a different role in bed dissection. It widens the PSP due to inflation of enclosed tissues forming a large aqueous zone within the plane limits. This facilitates keeping the process of gallbladder separation within PSP and reduces the chances for PSP violation and injury to surrounded structures (the liver, intrahepatic structures or gallbladder wall), (Fig..7). The separation of the gallbladder within the augmented proper plane is probably the better alternative to subtotal cholecystectomy as it does not leave inflamed tissue or intact mucosa behind. Hydrodissection also avoids excess bleeding which may occur in the fundus-first technique.

The second difficulty in bed dissection lies in identifying and subsequently managing crossing structures that traverse the bed to connect the gallbladder and the liver. These include veins, arteries and bile ducts. When the PSP is narrow, these crossing structures may be divided flush with the liver surface during the separation process. They present as spurters or observed bile leaking from within the liver rather than sizeable visible structures. Controlling bleeding vessels by electrocoagulation, under these conditions, carries the risk of parenchymal liver damage and bile duct injury [27].

Probably the more frequent of these structures are the veins. Venous drainage of the gallbladder occurs mainly through the bed. The bed route (crossing the GBM) is more frequent than the hilar route (through the liver hilum) as it was reported to be the principal route in 58% to 92% of cases [31,32].

Significant bleeding from these vessels is more likely in portal hypertension and cirrhosis [33,34]. In the era of open cholecystectomy, bleeding from the bed was the main cause of death in cirrhotic patients due to shock or triggering septic sequelae and liver failure [35]. Laparoscopic cholecystectomy is associated with lesser overall bleeding than open cholecystectomy in cirrhotic patients [33,36,37] yet serious bleeding from the bed still presents a major threat.

Bleeding from the veins crossing the bed is the most common complication of laparoscopic cholecystectomy in cirrhotic patients [38]. It is responsible of 66% of conversions in these cases [36]. This bleeding is the cause of the higher incidence of conversion in cirrhotic patients in comparison with the general population [33,39]. In the latter, the conversion rate reported in large groups of patients, ranged between 2.2 and 4.3% [5,23,40,41,42]. The incidence of conversion in cirrhotics was reported to be higher, ranging from 6 to 19% [36,43,44,45,46].

Branches of cystic arteries may also reach the gallbladder by crossing the GBM. This occurs in 4% of people when the cystic arteries lie deep in the gallbladder fossa beneath the GBM [47]. In 12% others, significant crossing arteries may lie at the edges of gallbladder fossa where anastomoses between the cystic artery and right and left hepatic arteries were reported [47].

Significant bile ducts may also cross the GBM. Cholecystohepatic ducts (ducts of Luschka) are accessory channels which connect intrahepatic ducts and the gallbladder [48]. Inability to identify these ducts during surgery was reported to result in postoperative biliary leak and peritonitis [49,50].

Identification and control of the vessels and ducts which cross the bed become more feasible with hydrodissection. This is due to one of its basic effects which is hydro-elongation. The widening of the PSP stretches crossing structures and allows visualization of longer portions of these structures during dissection. This effect has 2 benefits. First, it facilitates identification of these structures. Second, it also allows better control by diathermy, clips or ligatures at a suitable point in their

exposed length and avoids performing these procedures within the liver substance, (Fig. 8, 9).

The third difficulty in bed dissection is associated with cholecystectomy of an intrahepatic or inaccessible gallbladder (deeply seated in a large fatty liver or obscured by a large left lobe). Previously, suggestions were made to do less than a cholecystectomy when this difficulty is encountered, e.g. stone extraction and biliary tract drainage [51] or simple biliary drainage [52].

Hydrodissection helps in this situation by another basic effect which is hydro-elevation. The whole gallbladder is displaced into a more superficial and accessible position by extensive inflation of the PSP below it, (Fig. 4,10). Separation of the gallbladder from the liver is then carried within the huge aqueous zone, nearer to the gallbladder wall than the liver side. This arrangement has 2 benefits. First, it facilitates manipulation of the gallbladder after its superficialization. Second, it avoids maneuvering in the bottom of the resulting deep space for hemostasis or dissection with all the associated difficulties and hazards.

In the present study, the observed differences in the results of the two groups are significant. The significantly lower incidence of conversion, bleeding and gallbladder perforation, and the shorter operative time in the patients who had hydrodissection supports the argument about the value of the technique.

The zero% conversion rate associated with hydrodissection in difficult cases is remarkable. It indicates that the laparoscopic approach, coupled with devised, problem-oriented, supportive techniques, can parallel the open approach in feasibility. In view of established superiority of laparoscopic cholecystectomy over open cholecystectomy in almost all other aspects, designing suitable methods to deal with difficulties in laparoscopic surgery, as is the case with hydrodissection, leaves no place for conversion, in the future, as a concept. It indicates further maturation of laparoscopic surgery as an established discipline.

This study revealed several basic effects of hydrodissection that address specific difficulties and help to overcome them. They may prove to be useful tools in difficult situations during other laparoscopic procedures whenever an addressed difficulty indicating any of these effects is encountered.

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