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TYPE OF ARTICLE

Comparing Task Performance and Comfort during Nonpulmonary Video-assisted Thoracic Surgery Procedures Between the Application of the ‘Baseball Diamond’ and the ‘Triangle Target’ Principles of Port Placement in Swine Models

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ABSTRACT

Objective: The baseball diamond principle (BDP) is the conventional principle used for ports placement in video-assisted thoracic surgery (VATS). The triangle target principle (TTP) was introduced as an alternative principle where BDP is associated with difficulties especially in lung resections. We compared the task performance and surgeon's discomfort during some nonpulmonary VATS procedures between using the BDP and TTP in swine models.

Materials and methods: Thirty six nonpulmonary VATS procedures were done on swine models at the World Laparoscopy Hospital, Gurgaon, NCR Delhi, India from 19th February 2013 and 23rd March, 2014. The procedures are 12 VATS pericardial window, 12 oesophagocardiomyotomy and 12 thoracic sympathectomy (6 using BDP and 6 using TTP of each procedure). The outcome measures were the execution time, the errors rate and the surgeon's discomfort.

Result: Video-assisted thoracic surgery (VATS) pericardial window using TTP took longer time to be executed with a mean difference of 93 seconds when compared to using BDP but the errors rates and surgeon's discomfort was similar between BDP and TTP. VATS oesophagocardiomyotomy using BDP took longer time with a mean difference of 326.67 seconds but using the TTP was associated with more errors and surgeon's discomfort. In VATS thoracic sympathectomy using the BDP took longer time with a mean difference of 194 seconds, but the execution time data using BDP was not reproducible when validated statistically. The errors rates and surgeon's discomfort was similar between BDP and TTP.

Conclusion: Using baseball diamond principle appears to lead to better task performance and less Surgeon's discomfort during some nonpulmonary VATS procedures in swine models but there is need for studies with larger sample size. TTP use may be more favored during nonpulmonary VATS when stapling will be required.

Keywords: ....

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INTRODUCTION

Video-assisted thoracic surgery (VATS) or thoracoscopic surgeries refer to totally thoracoscopic approaches, where visualization is dependent on video monitors, and rib spreading is avoided by using a thoracoscope, video monitors and one to four small (1-2 cm) incisions.[1] VATS involve the use of ports through which long instruments including thoracoscope, graspers, scissors, forceps, retractors are passed into the chest cavity via 1 to 2 cm skin incisions. There are ergonomic principles governing the positioning and placement of these ports to facilitate task performance and surgeons comfort. These principles include:

- The optical trocar port is placed at the center so that the telescope will come to lie between the working instruments
- The instruments should act as type 1 lever with equal length inside and outside the peritoneal or thoracic cavity.
- The manipulation angle between the 2 working instruments should optimally be 60° (elevation angles of 30° and azithmus angle of 15°-45°)
- The working instruments should not face or work against the telescope as this leads to production of mirror image and difficult task execution with increased error rate.

To achieve above principles, the baseball diamond principal (BDP) is used in deciding the sites of ports placement. The BDP is the conventional principle used in laparoscopic and VATS.[2-5] In BDP the position of the baseball infielders (Infield players) is used as the position of the ports (Fig. 1). The optical port for the telescope is placed at the position of the catcher at the home plate, the 1st working instrument at the 1st baseman location, the target at

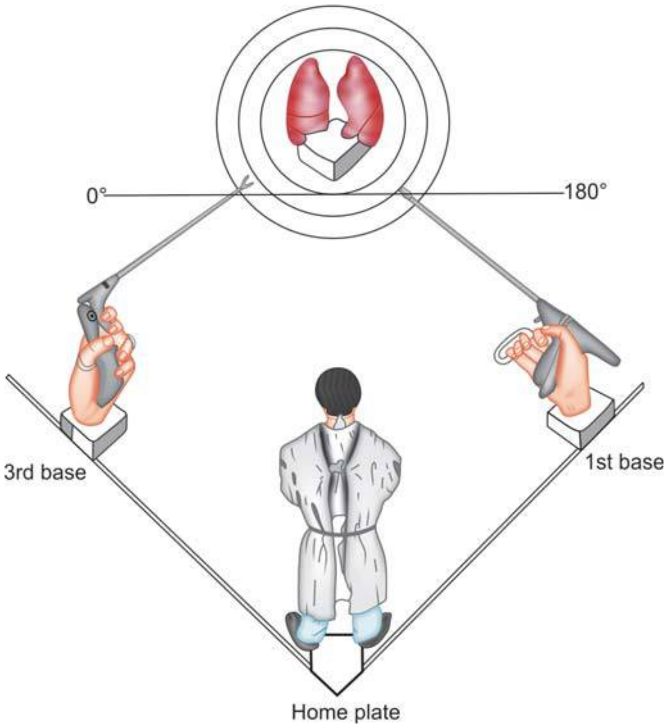

Fig. 1: Baseball diamond concept

the 2nd baseman position and the 2nd working instrument corresponds to the position of the 3rd baseman. Thus, the optical port is placed directly opposite the target and the working instruments are lateral to the optical port.

The experience that BDP may pose difficulties in some VATS procedures led to the introduction of an alternative principle to ensure better task performance. Sasaki et al[6] pointed to the difficulty they experienced in treating thoracic lesions especially peripheral lung lesions using the BDP and they developed and introduced the triangle target principle (TTP) to solve the difficulty. They also concluded that the application of TTP for ports placement can be used to access and treat all thoracic lesions. The TPP involves placing 3 ports to make an equilateral triangle between the optical port, the 1st working instrument and the target. A 3rd port (usually used for introduction of grasping forceps) is placed close to the target and hence called the target port (Fig. 2).

Most of the procedures done using the TTP when it was introduced involved lung resections and there is a need to assess the use of the TTP in nonpulmonary procedures and compare it with the conventional BDP.

MATERIALS AND METHODS

Thirty-six nonpulmonary VATS procedures were conducted on swine models by the candidate at the Institute of Minimal Access Surgery, the Global Open University in the World Laparoscopy Hospital, Gurgaon India over 6 months between 19/09/2013 and 23/03/2014. Twelve pigs were used and 3 procedures were done on each animal. The procedures include 12 pericardial window, 12 oesophagocardiomyotomy and 12 thoracic sympathectomy. Six of each of the procedures were done using BDP and six using TTP.

The outcome measures are execution time (seconds), errors (pericardial window-myocardial injury; oesophago-cardiomyotomy-oesophageal perforation, aortic injury and thoracic sympathectomy-intercostal vessels bleeding) and surgeons discomfort level as analyzed by visual analog system (VAS) ranging from 1 to 10 in increasing discomfort pattern.

The research was an animal study which is strictly regulated in India under the provisions of section 15 of the prevention of cruelty to Animals Act, 1960 and the rules under the Act of 1998 and 2001. This is enforced by the committee for the purpose of control and supervision of experiments on animals (CPCSEA).[7] In conducting this research the operational guidelines for observance of good practices by the CPCSEA was strictly adhered to. Permission and approval for procurement of the pigs from CPCSEA registered animal breeding houses and conduct of the research was obtained. At the end of the experiments euthanasia was induced and the animals carcasses were disposed according to the provisions.

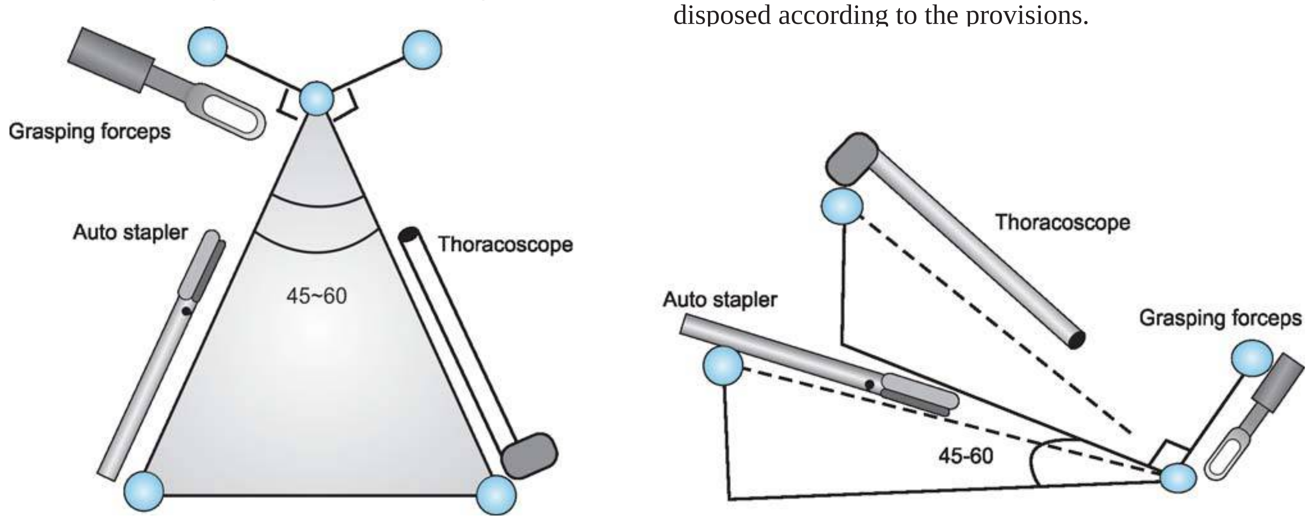

Fig. 2: ....

The animals were anesthetized (Ketamine, Propofol, Diazepam, Midazolam and Tramadol). The ports were created using surgical scalpel and air was insufflated into the chest cavity to collapse the ipsilateral lung. The optical trocar was inserted blindly while the working ports were inserted under vision. Pericardial window was done using a grasper and a scissors. Esophagocardiomyotomy was done with the alternating use of scissors, monopolar hook diathermy and grasper for retracting the lower lobe of the left lung. Monopolar hook diathermy was used to do thoracic sympathectomy. At the end of the procedure euthanasia was conducted by giving high dose of succinylcholine and the carcasses disposed appropriately.

There are some limitations of this research which include: (i) the small sample size because the study is on animal models which are not commonly used now because of stringent legislations and the limited time (ii) swine models have flimsy tissues and are easily injured and the space between the anterior and posterior axillary lines are shorter which limit exposure.

BDP *vs* TTP

Port Placement in VATS Pericardial Window

The ports placement for VATS pericardial window by the BDP requires putting the optical port at 8th intercostal space along the posterior axillary line, the 1st working port at the 6th intercostal space along the posterior axillary line and the 2nd working port at the 7th Intercostal space along the anterior axillary line.

The TTP requires placing the optical port at the 7th intercostal space along the posterior axillary line, the 1st working port at the 4th intercostal space along the posterior axillary line and the target port at the 3rd intercostal space along the midclavicular line (Fig. 3).

Port Placement in VATS Heller’s esophagocardiomyotomy

The ports placement for VATS Heller’s esophagocardio-myotomy by the BDP requires putting the optical port at 7th intercostal space along the midaxillary line, the 1st working port at the 8th intercostal space along the posterior axillary line and the 2nd working port at the 6th intercostal space along the posterior axillary line.

The TTP requires placing the optical port at the 7th intercostal space along the midaxillary line, the 1st working port at the 8th intercostal space along the posterior axillary line and the target port at the 5th intercostal space along the midaxillary line (Fig. 4).

Port Placement in VATS Thoracic Sympathectomy

The ports placement for VATS thoracic sympathectomy by the BDP requires putting the optical port at 5th intercostal space along the midaxillary line, the 1st working port at the 4th intercostal space along the posterior axillary line and the 2nd working port at the 3rd intercostal space along the anterior axillary line.

The TTP requires placing the optical port at the 7th intercostal space along the anterior axillary line, the 1st working port at the 8th intercostal space along the posterior axillary line and the target port at the 4th intercostal space along the midaxillary line (Fig. 5).

RESULT

VATS Pericardial Window

The mean execution time for VATS pericardial window using the BDP for ports placement was 561seconds (530-580 seconds). The mean time using the TTP for ports placement was 654 seconds (625-670 seconds). This shows a mean

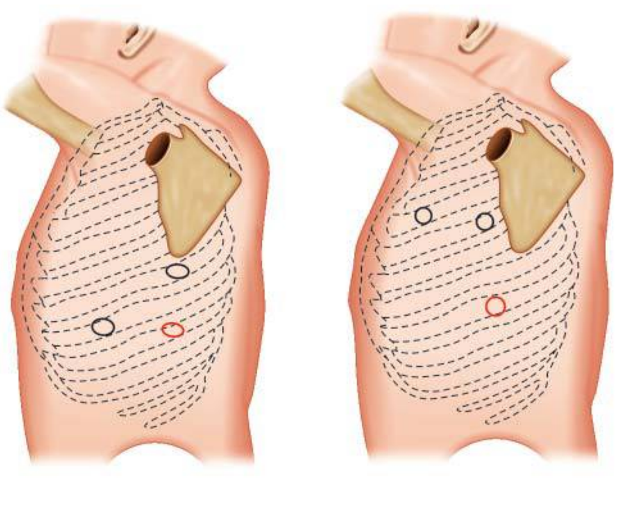

Fig. 3: Ports for VATS pericardial window: BDP *vs* TTP

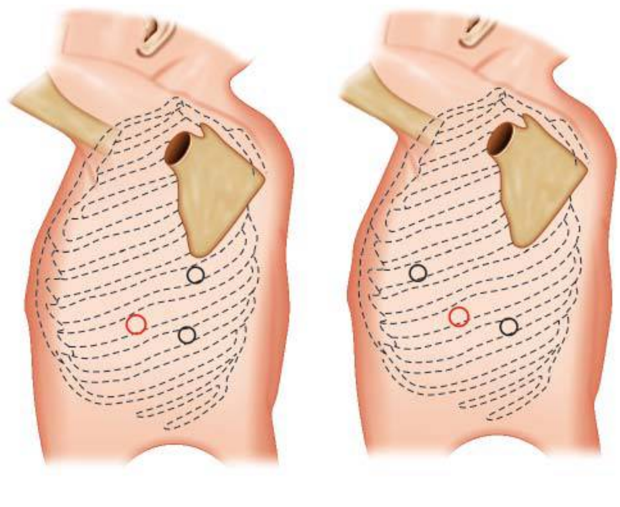

Fig. 4: Ports for VATS esophagocardiomyotomy: BDP *vs* TTP

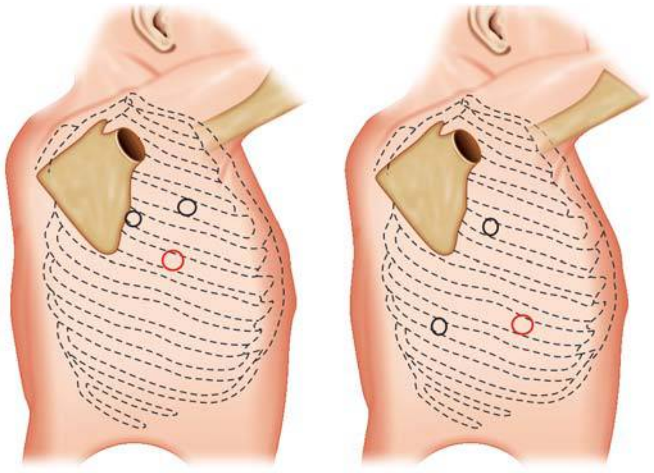

Fig. 5: Ports for VATS thoracic sympathectomy: BDP *vs* TTP

difference of 93 seconds with the TTP of port placement taking a longer time to execute (Table 1).

The data for the Execution time by using both the BDP and TTP were found to be statistically significant and reproducible using chi-square (χ^2-value of 2.649 and 2.734 respectively at a p-value of 11.07). Hence, the difference between the execution times when BDP and TTP were used was statistically significant and VATS pericardial window done using TTP takes a longer time to be executed.

There were no major errors (Myocardial injury) recorded while using both the BDP and TTP for port placement in VATS pericardial window. Thus, VATS pericardial window using BDP and TTP are comparable in terms of the error rates.

The surgeon's discomfort during VATS pericardial window using the BDP for port placement ranged from 3 to 5 (Mean of 3.83) and the discomfort when the TTP was used ranged from 3 to 6 (Mean of 4.17). VATS pericardial window between the application of BDP and TTP is comparable in terms of the surgeon's discomfort.

There was presence of mirror imaging when TTP was used which made the procedure difficult.

VATS Heller's Esophagocardiomyotomy

The mean execution time for VATS esophagocardiomyotomy using the BDP for ports placement was 1375 seconds (1360-1400 seconds). The mean time using the TTP for ports placement was 1048.33 seconds (1000-1100 seconds). This shows a mean difference of 326.67 seconds with the BDP of port placement taking a longer time to execute (Table 1).

The data for the execution time by using both the BDP and TTP were found to be statistically significant and reproducible using Chi-square, although BDP is more reproducible (χ^2-value of 0.797 and 7.90 respectively at a p-value of 11.07). Hence, the difference between the execution times when BDP and TTP were used was statistically significant and VATS esophagocardiomyotomy done using BDP takes a longer time to be executed.

There were major errors recorded while using both the BDP and TTP for port placement in VATS esophagocardiomyotomy. One episode of esophageal perforation was recorded using BDP while an episode of esophageal perforation and one aortic injury were recorded.

Thus, VATS esophagocardiomyotomy using BDP and TTP are comparable in terms of the error rates but TTP may be associated with more complications.

The surgeon's discomfort during VATS esophagocardiomyotomy using the BDP for port placement ranged from 4 to 7 (Mean of 5.83) and the discomfort when the TTP was used ranged from 6 to 8 (Mean of 7). VATS esophagocardiomyotomy using the application of TTP causes more discomfort to the surgeon than using the BDP.

VATS Thoracic Sympathectomy

The mean execution time for VATS thoracic sympathectomy using the BDP for ports placement was 656 seconds (590-700 seconds). The mean time using the TTP for ports placement was 462 seconds (432-505 seconds). This shows a mean difference of 194 seconds with the BDP of port placement taking a longer time to execute (Table 1).

The data for the execution time by using the BDP was not significant and not reproducible (χ^2 of 21.04) but that by using TTP was statistically significant and reproducible using Chi-square (χ^2-value of 7.80 at a p-value of 11.07). VATS thoracic sympathectomy done using BDP takes longer time to be executed, although the BDP data is not reproducible.

Table 1: Execution time (seconds) for VATS pericardial window, esophagocardiomyotomy and thoracic sympathectomy between BDP and TTP

S. no.	*VATS PW*		*VATS OCM*		*VATS TS*	
	BDP	*TTP*	*BDP*	*TTP*	*BDP*	*TTP*
1.	580	670	1360	1010	700	505
2.	555	670	1370	1080	650	470
3.	570	644	1365	1100	700	435
4.	570	670	1370	1070	596	460
5.	530	645	1385	1030	590	470
6.	561	625	1400	1000	700	432
Mean	561	654	1375	1048.33	656	462

There was one episode of major errors (Intercostal vessels injury) recorded while using both the BDP and TTP for port placement in VATS thoracic sympathectomy. Thus, VATS thoracic sympathectomy using BDP and TTP are comparable in terms of the error rates.

The surgeon's discomfort during VATS thoracic sympathectomy using the BDP for port placement ranged from 4 to 6 (Mean of 4.83) and the same discomfort level was obtained when the TTP was used. VATS thoracic sympathectomy between the application of BDP and TTP is comparable in terms of the surgeon's discomfort.

DISCUSSION

The BDP is the conventional principle for deciding sites of port placement during VATS.[1-3,8] It is the background principle to which other principles are compared.

VATS Pericardial Window

The result showed that using the TTP for ports placement led to longer execution time with a mean difference of 93 seconds. The error rates and the surgeons discomfort were however similar.

The prolonged execution time may be attributable to the mirror image produced when TTP is used. The scissors and the grasping forceps were often alternated between the working port and the target port during the procedure to conform to the different orientations for resecting the pericardial segment. The mirror image distorts the visuals and the orientation which prolongs the execution time.

With more experience this problem may be addressed by maintaining the grasping forceps in the target port and cutting the pericardial segment with a scissors or monopolar spatula through the working port.

The TTP may have a role when dealing with pericardial lesions requiring digital palpation and stapling such as pericardial cysts. The manipulation angle between the grasping forceps and the stapler (through the target and working ports respectively) is then 90° which is the perfect angle for stapling. When BDP is used in this scenario, a different access may be required for the stapler to achieve this angle.

Thus, BDP is preferred for ports placement during VATS pericardial window but TTP may have clear advantages when dealing with pericardial lesions requiring digital palpation and stapling.

VATS Esophagocardiomyotomy

From the results the execution time for VATS esophagocardiomyotomy using BDP for ports placement was more than when TTP was used with a mean difference of 326.67 seconds. This is in contrast to the results of the errors rates and surgeons discomfort which were more when TTP was used.

One episode of esophageal perforation was recorded when using the BDP while 2 major errors (esophageal perforation and descending aortic injury) were recorded when TTP was used. This is significant as it translates to 33.3% error rate.

The surgeon's discomfort using TTP was worse with an average of 7 compared to 5.83 recorded for BDP.

The increased error rates and surgeon's discomfort can be explained by the mirror image produced when using TTP and the flimsy nature of the pig's tissue giving rise to injury to the esophagus and the surrounding structures even with minimal force.

The prolongation of the execution time when BDP was used which is in contrast to the trends of the error rates and the surgeon's discomfort could have been due to the increased error rates in TTP use. When these major errors are encountered, the procedure do not usually proceed and the execution time when using TTP is recorded as shortened. This calls for more data from larger sample size to revalidate this and offer more explanations.

The BDP appears to be better than the TTP of ports placement for VATS esophagocardiomyotomy in terms of the error rates and the surgeon's discomfort, although it took longer time to be executed.

The TTP may have clear advantages over BDP when treating other esophageal diseases requiring stapling such as esophageal diverticulum or during esophagectomy due to the 90° manipulation angle between the grasping forceps and the stapler.

VATS Thoracic Sympathectomy

The execution time for VATS thoracic sympathectomy when using the TTP was less than when BDP was used (Mean difference of 194 seconds). But the execution time data is not statistically significant and so not reproducible ($\chi^2 = 21.04$ at p-value of 11.07). Thus, there may be need for a larger sample to reassess its reproducibility and then objectively compare it with the TTP. The BDP and the TTP are comparable in terms of the error rates and the surgeons discomfort.

It can also be seen that TTP is comparable or more favorable to BDP when the instrument through the target port is used for retraction only and not for other manipulations. When used for other purposes, the mirror image produced will lead to reduced task performance and increase surgeon's discomfort.

CONCLUSION

The BDP is the conventional principle used to decide sites for port placement during VATS. The TTP was introduced as an alternative principle when difficulty was observed during some procedures using the BDP especially pulmonary procedures. This thesis compares the 2 principles during VATS pericardial window, VATS esophagocardiomyotomy and VATS thoracic sympathectomy.

The BDP appears to be associated with better task performance in terms of the execution time and error rates and has less surgeons discomfort during some nonpulmonary VATS procedures in swine models compared to the TTP when stapling is not required.

The TTP may offer more advantages when the instrument passed through the target port is used only for retraction and also in VATS procedures where stapling may be required.

The prolonged execution time associated with BDP during VATS esophagocardiomyotomy and VATS thoracic sympathectomy needs further evaluation with a large data.

RECOMMENDATIONS

- The BDP should be preferred during nonpulmonary VATS procedures when stapling may not be required
- The TTP should be preferred during nonpulmonary VATS procedures when the instrument through the target port is used only for retraction or stapling will be required
- There is need for a larger sample size to have a more reproducible and validated result
- There should be caution when translating this data to humans as the swine models have some peculiarities such as flimsy tissues and shortened space between the anterior and posterior axillary lines
- Surgical simulation using animal models is a high fidelity method and should be encouraged when ever feasible
- An alternative to the swine models should be considered for VATS procedures. The sheep models have stronger tissues and are an option.

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