

Efficacy and Safety of Splanchnic Nerve Neurolysis via the Transdiscal Approach Using CT/Ultrasound Dual-Guided Posterior Approach in the Management of Upper Abdominal Cancer Pain: A Retrospective Analysis

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Objective: To evaluate the effectiveness and safety of CT/ultrasound dual-modality guided posterior approach in the management of upper abdominal cancer pain.

Study Design: Clinical research study.

Methods: A total of 19 patients (7 men and 12 women) who had advanced carcinomatous epigastric pain and match the selection criteria were recruited in this study. All the patients proceed the bilateral Splanchnic Nerve Neurolysis (SNN) under Computed Tomography (CT) guided and Ultrasound. The pain Numerical Rating Scale (NRS) at different times (T0: preprocedure, T1: 1 day after-procedure, T2: 1 weeks, T3 and T4: 4 and 8 weeks after-procedure and drug taken dosages were recorded. The incidence of complications was also assessed.

Results: All the patients were successfully completed procedures under CT/Ultrasound dual-guided. NRS exhibited significant differences when comparing the preoperative time point (T0) with each of the following time intervals (T1-T4) (**P < 0.001). As the NRS gradually decreased, significant differences were observed between T2 and T3 (**P < 0.05). However, no significant difference was found between T3 and T4 regarding pain scores (p = 0.331). The consumption of morphine was significantly lower postoperatively than preoperatively, with the most pronounced reduction observed on the first day after surgery (**P < 0.001). Nevertheless, no statistically significant differences were observed at the other time intervals (P > 0.05). No severe complications during or after the surgery. Two patients (10.5%) felt burning pain in the abdomen for 2 days, 1 patient had transient backache for 3 days, and 12 (63.2%) patients had diarrhea for 1 week and disappear.

Conclusion: The CT/Ultrasound dual-guided SNN procedure is regarded as a efficacy and safety treatment for managing abdominal cancer pain. It increases constant visualization in the operation and reduces radiation exposure.

Plain Language Summary: Cancer-related abdominal pain has a significant impact on terminally ill patients, they cannot solely rely on oral medications for pain relief. Neurodestructive interventional therapy can provide a surprising solution. Due to anatomical characteristics, visceral nerve destruction is easier to perform and special recommended for patients with advanced adhesional tumors. The combined use of CT and ultrasound increases accuracy and constant observation while reducing radiation exposure, which we highly recommend.

Keywords: splanchnic nerve neurolysis (SNN), abdominal cancer pain, CT, ultrasound

Introduction

The percutaneous neurolytic celiac plexus block (NCPB) and splanchnic nerve block, first reported by Kappis and Popper, respectively, have been recognized as effective strategies for alleviating visceral pain in the upper abdominal region.^{1,2} These techniques have been recognized as effective strategies for alleviating visceral pain in the upper abdominal region. Since the advent of new imaging techniques, such as the transition from x-ray to computed tomography (CT) and ultrasound, the injection position has become more visually accurate, drug diffusion is clearer, and the later treatment effect can be estimated.^{3,4} In the context of advanced malignancies, the anatomical structure of the celiac plexus may become altered due to the presence of the underlying cancer or the enlargement of adjacent celiac lymph nodes. This distortion makes it difficult to access the celiac ganglia and may result in insufficient distribution of the neurolytic agent. This was also confirmed by poor drug diffusion on CT imaging.⁴ In these situations, SNN performed by injection of neurolytic solution behind the crura of the diaphragm, is useful because its anatomy is rarely affected by the carcinoma or enlarged lymph nodes. The splanchnic nerve acts as one part of source of the celiac plexus. The celiac plexus consists of nociceptive afferent fibers that come from not only the upper abdominal parenchymatous organs (such as the liver, pancreas, and spleen) but also from other visceral organs such as the stomach, intestines, and lower abdominal and pelvic organs, including the large intestine (up to the transverse colon), bladder, and reproductive organs in females. This plexus is located posterior to the diaphragm crura and penetrates through them at the T11-12 vertebral levels to connect with the celiac ganglion.^{3,5} In clinical practice, for splanchnic nerve neurolysis, the needle only needs to reach the bilateral lateral edges of the vertebral bodies in the retrocrural space, not the depth needed for celiac plexus block. The retrocrural space (RCS) can be defined as a triangular region that represents the lower portion of the posterior mediastinum containing neural structures (sympathetic trunk and splanchnic nerves). Splanchnic neurolysis is successful when we inject alcohol into the RCS.^{3,6} Numerous studies have demonstrated that SNN provides superior pain alleviation, reduced reliance on opioids, a lower incidence of complications, and an enhanced quality of life (QOL) compared with the neurolytic celiac plexus block (NCPB).^{7,8} Additionally, patients experience prolonged pain relief and greater satisfaction following SNN compared with NCPB.⁹ However, in interventional treatment methods, we know that only by reaching the precise disease target can we achieve effective result. Although the transition from X-ray scanning to CT increases the accuracy, it also loses the constant visualization and increases the radiation dose. Therefore, we explored the posterior approach by Ultrasound for the first time in the SNN approach, in conjunction with CT calculations expected to increase accuracy while reducing radiation dose.

Here, we reported 19 cases patients using bilateral splanchnic neurolysis under CT/Ultrasound dual guidance for treating severe abdominal pain.

Methods

Ethical Approval

This research received approval from the Medical Ethics Committee at the Affiliated Hospital of Jiaying University (2022-LY-414). All participants consented to partake in the study procedures and authorized the use of their imaging data for retrospective research and publications. The study was carried out in alignment with the principles outlined in the Declaration of Helsinki. Informed consent was duly obtained from each patient involved in the study.

Patients

Nineteen patients who were referred from the pain department of the Affiliated Hospital of Jiaying University between February 2023 and December 2024 and suffering from advanced cancer presented with upper abdominal visceral pain. They all received SNN by CT/Ultrasound dual-guided, including 7 men and 12 women, aged 46–86 years and Duration of disease were 7–58 months. Among the patients, liver cancer 8 cases, pancreas carcinoma 7 cases and cholangiocarcinoma 4 cases were enrolled in this study. All patients had a grade III or IV physical status on the classification system established by the American Society of Anesthesiologists.

Inclusion and Exclusion Criteria

Inclusion Criteria

1. all patients had a grade III or IV physical status on the classification system established by the American Society of Anesthesiologists.
2. cancer induced upper abdominal visceral pain; (2) numeric rating scale (NRS) score ≥ 7 after opioid therapy and intolerable side effects; and
3. platelets, coagulation time, and prothrombin time were normal; there was no skin infection near the puncture site; and (4) Patients can tolerate a half-hour surgery in the prone position.

Exclusion Criteria

1. ASA IV patients who are unable to withstand surgical procedures; (2) presence of a cutaneous infection or neoplasm at the designated treatment area; and (3) coagulation dysfunction, (4) patients' refusals to participate.

Procedure

Each patient was given capacity expansion treatment two days before surgery with 2000mL crystalloids solution slowly infusion with Cardiac function monitoring and intravenous access should be established and received rapid 0.9% saline 500mL infusion before surgery and prophylactic antibiotic administration on the day of the surgery for maintain blood pressure stability. The patient was positioned face down with a cushion supporting the upper abdomen and was administered inhaled oxygen at a flow rate of 2 L/min with a nasal cannula. ECG monitoring, blood pressure was performed continuously during the whole operation. The positioning grid was fixed near the vertebral bodies of T11 and T12 with adhesive tape (Figure 1A). The T11–T12 intervertebral space was found through CT, and marked the puncture level, at which the puncture path was then designed (Figure 1B). Target points were the anterior lateral margin of the vertebral body, and the bilateral puncture pathways both pass through the intervertebral discs. The pulsed radiofrequency (PRF) needle, sized 20 G, 150 mm long, with a working end length of 10 mm, was inserted along the designated path by CT after routine skin sterilization and local anesthesia. To minimize radiation exposure from CT scans and obtain constant observation, we have took ultrasound guidance to precisely target the intervertebral disc through the entry point (see Figure 2). First, we identify the vertical plane of the target intervertebral disc under ultrasound using the puncture line from the CT scan (Figure 2A: blue line1). Next, we put the ultrasound probe (Sonosite X-PORTE, UJIFILM Sonosite, Inc., Bothell, Washington, a low-frequency convex array transducer 5–2MHz) parallel to the intervertebral disc plane, which represents the short axis of the vertebral body (Figure 2A blue bar), to visualize the upper and lower facet joint planes as shown in the CT images (Figure 2B: sAP, iAP, SP, red underline showed sAP and iAP). Then, guided by the ultrasound, we perform the puncture at the previously identified entry point. The ultrasound image reveals the spinous process, upper and lower facet joints (Figure 2B red underline showed sAP and iAP), and pleura, enabling us to identify the location of the distal intervertebral disc, at the same time in the path we measured the depth in the disc (Figure 1B red double arrow). This CT/ Ultrasound dual-guided procedure can minimize the risk of damaging surrounding tissues and organs (Figure 2C and D). Following this, the needle was advanced into the disc space and continue going to the depth which showed as the double red arrow in Figure 1B. The needle was then slowly and small advanced until a breakthrough sensation happened. We confirmed the location by CT scan again after injected a mixture of 0.5–1mL of 1% lidocaine and contrast medium. If the position was accurate, we first put a radiofrequency electrode to the target site and apply radiofrequency energy at 90°C for 5 minutes (Figure 1D). Subsequently, 5 mL mixture liquid (1% lidocaine and contrast medium) was injected to observe the distribution of the medication. The last, 5 mL of absolute ethanol (Hangzhou Qingchen Chemical Reagent Factory, 95% ethanol 500mL) is administered bilaterally (Figure 1E), and drug spread in the retrocrural space (Figure 3 the dotted line). After the procedure, the needle was withdrawn, and the puncture site was covered with a sterile dressing. Following a 20-minute observation period, the patient was transported back to

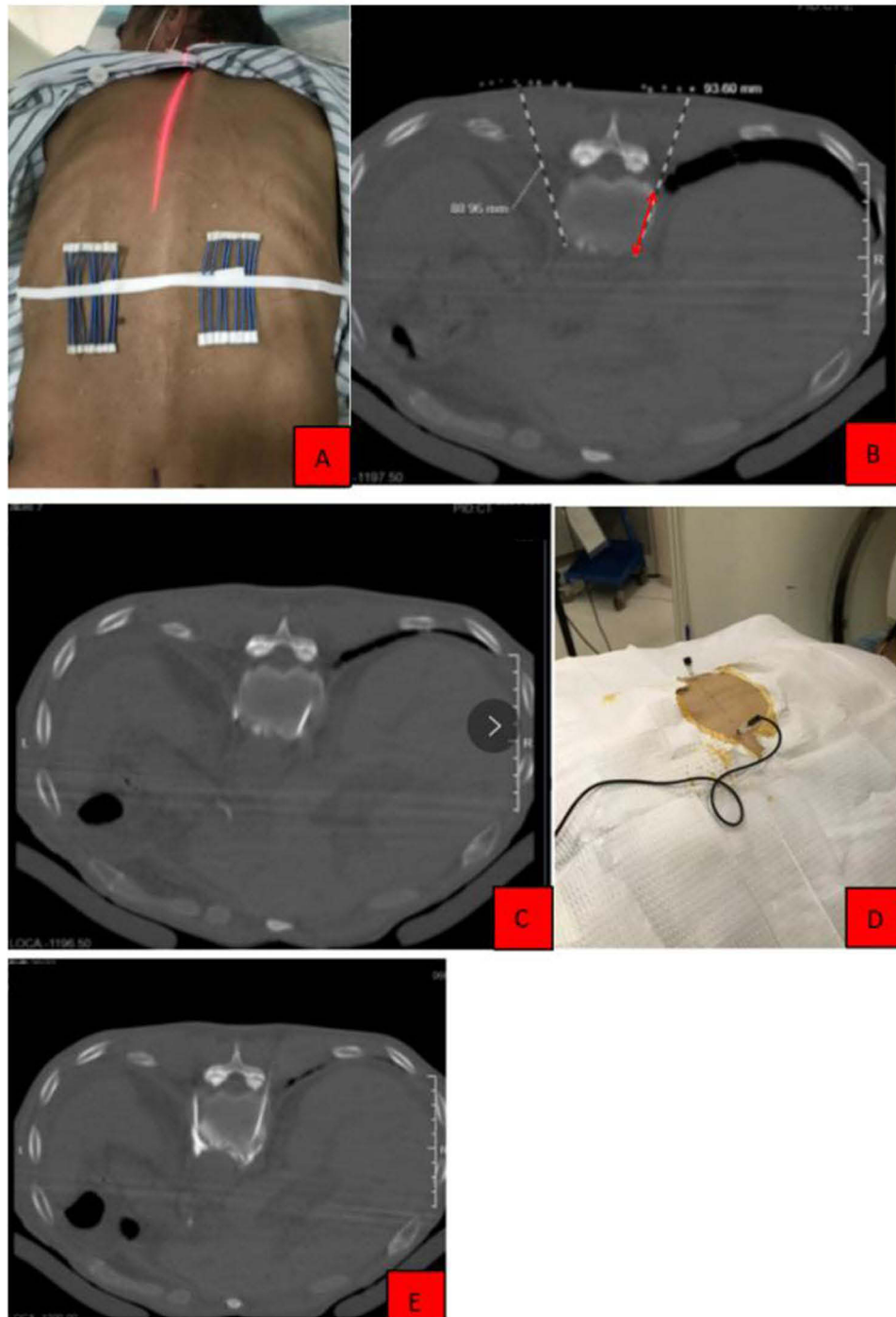


Figure 1 The patient was placed in a prone position with a pillow under the upper abdomen with vital sign monitoring during the whole operation. The positioning grid was fixed near the vertebral bodies of T11 and T12 with adhesive tape (A). The T11–T12 intervertebral space was found through CT, and marked the puncture level, at which the puncture path was then designed. At the same time in the path we measured the depth in the disc such as the red double arrow (B). By 1-B showed the depth CT images, we perform a secondary scan upon reaching the predetermined depth (C). To prolong the duration of nerve ablation, we first introduce a radiofrequency electrode to the target site and apply radiofrequency energy at 90°C for 5 minutes (D). Then mixture of 5 mL of 1% lidocaine and contrast medium is injected to observe the spread of the drug. Finally, 5 mL of absolute ethanol is administered bilaterally (E).

the ward. Within the first 24 hours after the procedure, strenuous activities should be avoided. Patients are advised to maintain a prone position for 2 hours to facilitate recovery. Additionally, it is crucial to keep the puncture site dry to prevent infection.

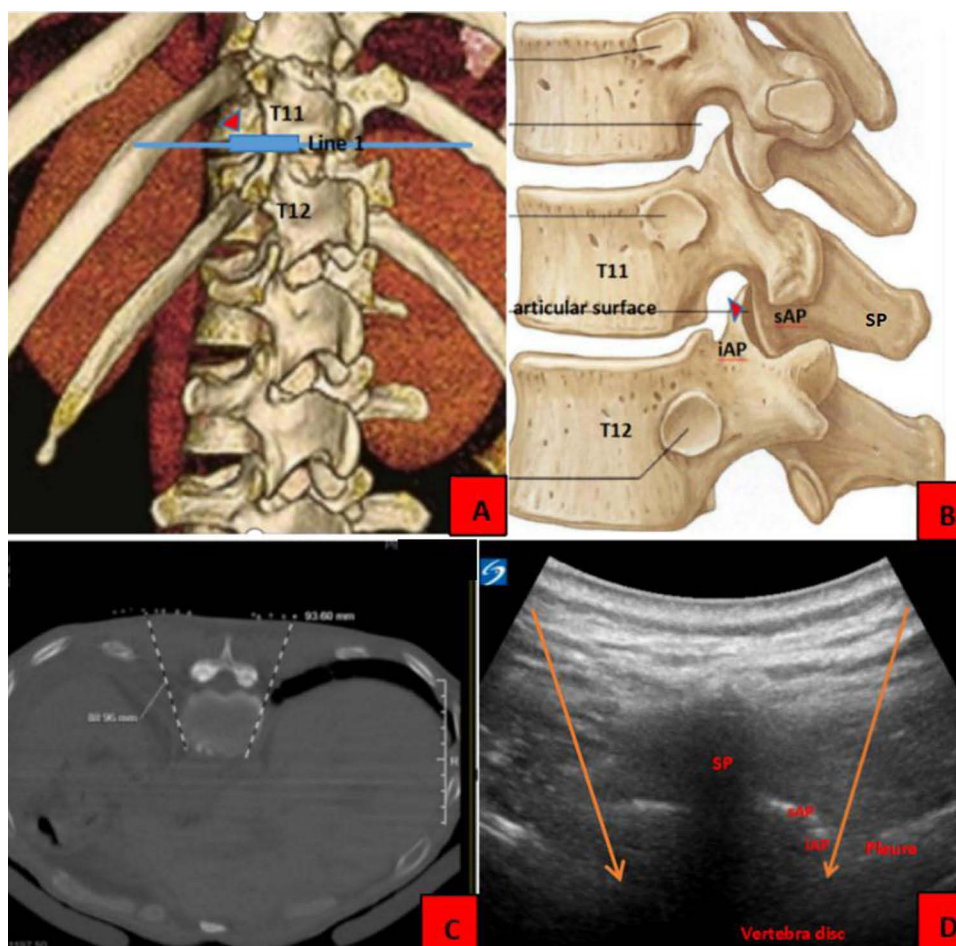


Figure 2 Blue line 1 showed the vertical plane of the target intervertebral disc T11-12 ((A) line 1), and then placed the ultrasound probe ((A) blue bar) parallel to the intervertebral disc plane (the red arrow in (A)). This plane can visualize the spinous processes ((B) SP, (D) SP) and the superior and inferior articular processes B-iAP/sAP, red underline showed iAP/sAP, respectively. According to the imaging guidance of CT (C), adjust the ultrasound probe to display ultrasound images of the same layer as much as possible, and continuously advance the needle under ultrasound (D). Orange arrow representative puncture path (D).

Observation Indexes

The collected data included:

- Collection general information of patients (Table 1).
- The NRS scores were assessed at various time points (T0: preprocedure, T1: 1 day after-procedure, T2: 1 weeks, T3 and T4: 4 and 8 weeks after-procedure) (Table 2)
- The quantity of morphine equivalents utilized was documented throughout the follow-up period (Table 3).
- The adverse effects or complications associated with the surgical procedure were documented, encompassing hypotension, diarrhea, pneumothorax, back pain, discitis, and paresthesia (Table 4).

Statistical Analysis

Data analysis was conducted by SPSS 25.0 (IBM, Chicago, USA). The Shapiro–Wilk test was performed to determine whether the measurements were normally distributed. Normally distributed data were expressed as mean \pm standard deviation, whereas non-normally distributed data were expressed as median (IQR). The Mann–Whitney *U*-test or independent *t*-test was performed for continuous variables. The Kruskal–Wallis test was used to analyze the Morphine equivalent and NRS score at each time interval after the operation, Multiple comparisons were performed by the Bonferroni test, and the significance level was corrected.

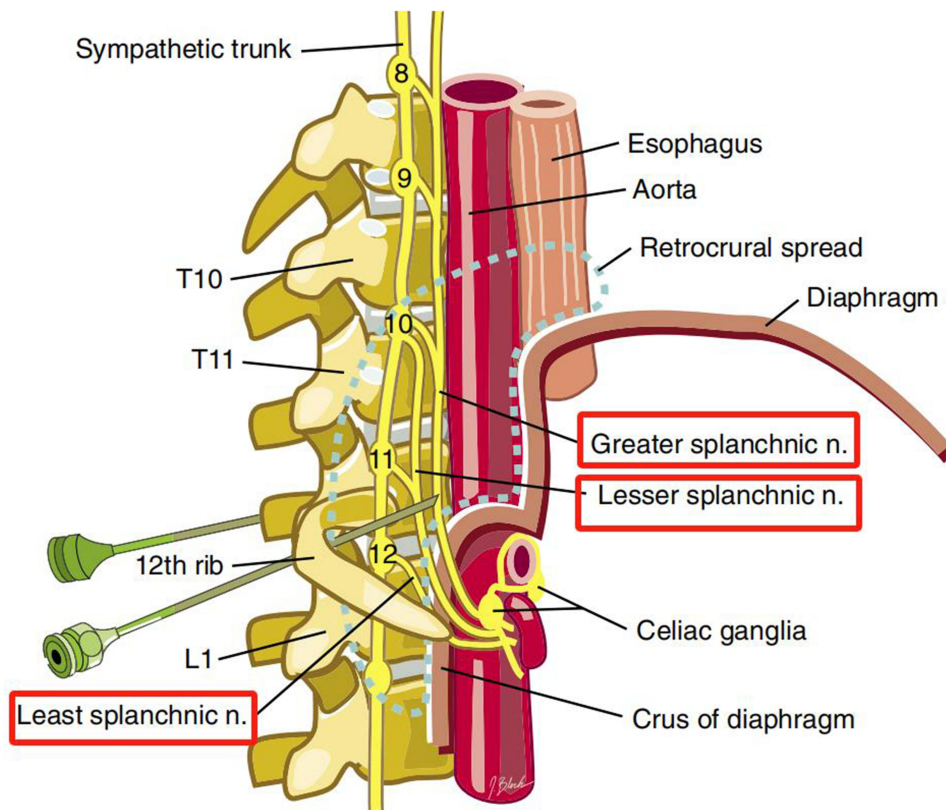


Figure 3 The greater splanchnic nerve at T5–T9 and the small splanchnic nerve at T10–T12, which originate from the T5–T12 spinal cord segments, descend anterolaterally along the corresponding vertebral body. These nerves enter the abdominal cavity through the esophageal hiatus of the diaphragm. When our needle passes through the T11–12 disc plane into the anterior edge of the vertebral body, we will reach a space called the retrocrural space (the dotted lines showed), which contains Greater splanchnic nerve, Lesser splanchnic nerve and Least splanchnic nerve (red box), viscera size and the smallest nerves. When ethanol is administered, it spread in the retrocrural space (the dotted lines showed) and it worked. Reprinted from Atlas of Interventional Pain Management, 4th Edition, Waldman SD, Chapter 97 - Lumbar Epidural Nerve Block: Interlaminar Approach, 499–505, 2014, with permission from Elsevier.

Result

Patient Characteristics

In total, 19 patients were successfully punctured under Ultrasound combined with CT guidance. The mean age of the included patients (7m/12f) was 65.26±8.08 (range 46–85 years). Duration of disease was 27 (IQR 23), with 8 cases of

Table 1 Patient Demographics and Baseline Data

| | |
|--|-------------|
| Total number of patients (February 2023–December 2024) | 19 |
| Age (years) Meas±SD | 65.26±8.08 |
| Sex (M/F) | 7/12 |
| Duration of disease (months) M(IQR) | 27 (23) |
| Morphine equivalent(mg) preprocedure Meas±SD | 71.58±20.35 |
| NRS preprocedure Meas±SD | 7.11±0.57 |
| Disease characteristic | |
| Liver cancer | 8 |
| Pancrease carcinoma | 7 |
| Cholangiocarcinoma | 4 |

Table 2 Comparison of Pre- and Post-operative NRS Scores

| | T0 | T1 | T2 | T3 | T4 |
|-----|-------------|---------------|---------------|---------------|---------------|
| N | 19 | 19 | 19 | 19 | 19 |
| NRS | 7.105±0.130 | 2.737±0.872 | 2.474±1.073 | 2.947±1.026 | 3.158±1.573 |
| T0 | — | P < 0.0001*** | P < 0.0001*** | P < 0.0001*** | P < 0.0001*** |
| T1 | — | — | P = 0.205 | P = 0.385 | P = 0.249 |
| T2 | — | — | — | P = 0.003** | P = 0.033** |
| T3 | — | — | — | — | P = 0.331 |
| T4 | — | — | — | — | — |

Notes: **P < 0.05, ***P < 0.0001 (significant differences). NRS revealed significant differences between the preoperative time point (T0) and each of the subsequent time points (T1-T4) (***P < 0.001). As NRS gradually decreased, significant differences were observed between T2 and T3 (**P < 0.05). However, no significant difference was found between T3 and T4 regarding pain levels (p = 0.331).

Abbreviations: NRS, numerical rating scale; T0, preoperation; T1, 1 day postoperation; T2, 7 days postoperation; T3, 30 days postoperation; T4, 60 days postoperation.

Table 3 Comparison of Pre- and Post-operative Opioid Dosage

| | T0 | T1 | T2 | T3 | T4 |
|-----|---------------|---------------|---------------|---------------|---------------|
| N | 19 | 19 | 19 | 19 | 19 |
| NRS | 71.579±20.348 | 45.263±17.438 | 44.737±23.657 | 42.105±23.939 | 41.053±25.363 |
| T0 | — | P < 0.0001*** | P < 0.0001*** | P < 0.0001*** | P < 0.0001*** |
| T1 | — | — | P = 0.848 | P = 0.380 | P = 0.297 |
| T2 | — | — | — | P = 0.235 | P = 0.202 |
| T3 | — | — | — | — | P = 0.331 |
| T4 | — | — | — | — | — |

Notes: ***P < 0.0001 (significant differences). The consumption of morphine was significantly lower post-operatively than preoperatively, with the most pronounced reduction observed on the first day after surgery (***P < 0.0001). However, no statistically significant differences were found at other time points (P > 0.05).

Abbreviations: T0, preoperation; T1, 1 day postoperation; T2, 1 week postoperation; T3, 1 month post-operation; T4, 2 month postoperation.

Table 4 Intra-operative and Post-operative Complications

| | |
|-----------------------------|------------|
| Hypotension | 0 |
| Burning pain in the abdomen | 2 (10.5%) |
| Transient backache | 1(5.3%) |
| Pneumothorax | 0 |
| Diarrhea | 12 (63.2%) |
| Paraplegia | 0 |
| Discitis | 0 |

Notes: There were no severe complications during or after the surgery. 2 patients (10.5%) felt burning pain in the abdomen for 2 days, 1 patient had transient backache for 3 days, and 12 (63.2%) patients had diarrhea for 1 week and disappear. No patient found hypotension, pneumothorax, and paraplegia.

liver cancer, 7 cases of pancreas carcinoma, and 4 cases of cholangiocarcinoma. NRS before procedure was 7.11 ± 0.57 , and Morphine equivalent preprocedure was 71.58 ± 20.35 mg (Table 1).

NRS Score

Data on the three-time points of pain scores (NRS), namely, preprocedure, postprocedure at 1 days, 1 week, 1 month and 2 months were collected. The NRS revealed significant differences between the preoperative time point (T0) and each of the subsequent time points (T1-T4) ($***P < 0.001$). As NRS gradually decreased, significant differences were observed between T2 and T3 ($**P < 0.05$). However, no significant difference was found between T3 and T4 regarding pain levels ($p = 0.331$) (Table 2).

Dosages Analysis of the Morphine Equivalent

The consumption of morphine was significantly lower postoperatively than preoperatively, with the most pronounced reduction observed on the first day after surgery ($***P < 0.001$). Nevertheless, no statistically significant differences were observed at the other time intervals ($P > 0.05$). One patient even stopped taking morphine at 1 month and 2 patients at 2 months after the procedure (Table 3).

Operation Related Complications

Based on past experience, the complications of the SNN include hypotension, burning pain in the abdomen, transient backache, pneumothorax, transient paresthesia, diarrhea, and paraplegia. In our study, 2 (10.5%) patients felt burning pain in the abdomen but disappeared 2 days later. One (5.3%) patient had transient backache for 3 days. Twelve (63.2%) patients had diarrhea for 1 week and disappeared. No patient found hypotension, pneumothorax, discitis, and paraplegia (Table 4).

Discussion

Cancer-related pain is one of the most common symptoms in patients with malignancy diseases, it affects 48% of patients with early tumor and 75% of patients with terminal diseases.^{10,11} Minimally invasive interventional neurolysis can significantly improve the quality of life for patients with advanced cancer pain and reduce the side effects of oral medications, which is of great significance for this patient population. This treatment modality is also gaining increasing recognition.¹² The main technique employed for SNN puncture is the retrocrural or paravertebral approach, which is conducted with the assistance of fluoroscopy or computed tomography (CT). Utilizing the paravertebral route under fluoroscopic guidance poses potential risks, including pneumothorax and vascular damage.¹³ Consequently, the use of SNN under computed tomography (CT) guidance offers distinct advantages, and the transdiscal approach may further minimize the risk of damage to the surrounding paraspinal structures.¹⁴

With the continuous advancement of imaging technology, our requirements for treatment imaging have become increasingly stringent. This progress ensures greater accuracy in patient treatment, thereby improving therapeutic outcome. However, the associated increase in radiation dose has also garnered significant attention in clinical practice, therefore, most of the reports in the clinic are fluorescent X-ray guidance.^{6,7,15} Therefore, our research incorporated ultrasound guidance to minimize the number of CT scans while still accurately observing the needle's position and the diffusion of the medication, thereby better estimating the treatment effect. This combined skill is very suitable for beginners.

The greater splanchnic nerve at T5–T9 and the small splanchnic nerve at T10–T12, which originate from the T5–T12 spinal cord segments, descend anterolaterally along the corresponding vertebral body. These nerves enter the abdominal cavity through the esophageal hiatus of the diaphragm. In our study, we chose T11–12 intervertebral disc space.^{16,17} In our study, we chose to insert the needle at the intervertebral disc space between thoracic vertebrae 11 and 12. This particular site selection significantly reduces the risk of pneumothorax and penetrates the anterior longitudinal ligament to diffuse the medication to the target area. Moreover, as the medication diffuses, the drug spreads into the retrocrural space (the dotted lines showed in Figure 3), it can block a broader range of neural pathways containing greater/Lesser/Least splanchnic nerves (Figure 3 red boxes).

Raj et al in 1999 based on the anatomic location of thoracic splanchnic nerves, which makes them the perfect target for selective radiofrequency ablation.^{18,19} In our research, we also associated with radiofrequency therapy. However,

according to anatomical observations, the locations of the splanchnic nerves are relatively dispersed (Figure 3 red boxes). In clinical practice, we found that radiofrequency alone could not get satisfied efficacy. Therefore, we combined radiofrequency therapy with SNN. Future perspectives will focus on the precise RF sites in SNN.

The traditional neurolysis for upper abdominal cancer pain primarily targets the celiac plexus and splanchnic nerves. These two approaches differ in needle insertion sites. Previous studies have compared these methods and concluded that splanchnic nerve neurolysis offers fewer side effects, longer-lasting pain relief, and easier operability.²⁰ In our research, we also found that splanchnic nerve neurolysis has minimal side effects, with an ethanol volume of no more than 10 mL. Moreover, it can be combined with radiofrequency treatment, an advantage not available with celiac plexus neurolysis.

Overall, SNN is highly significant in the treatment of upper abdominal cancer pain. We recommend CT/Ultrasound guidance, which can obtain constantly observation the injection process and increases accuracy, also can decrease radiation exposure.

Limitations

Small sample size, the single-center study, and the development of ultrasound still needs further research.

Conclusion

The CT/Ultrasound dual-guided Splanchnic Nerve ablation procedure is regarded as a safe and effective treatment for managing abdominal cancer pain, as it reduces radiation exposure.

Ethics Approval

Ethical approval for this study was obtained from the Affiliated Hospital of Jiaying University under the reference number 2022-LY-414. Informed consent: All patients read and signed the informed consent before the operation, with the patient's name withheld in this study.

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Disclosure

The authors declare no conflicts of interest with regard to the work.

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