Perioperative acupuncture modulation: more than anaesthesia

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Abstract

Accumulated evidences from clinical trials and updated reviews suggest that the role of acupuncture in perioperative medicine extends beyond the classical scope of anaesthesia and has been underestimated. Perioperative acupuncture reduces not only the consumption of anaesthetics and analgesics, but also anaesthesia-related complications, and protects organs in the perioperative period. These beneficial effects make acupuncture a promising approach in perioperative management, especially with respect to enhanced surgery recovery and specific surgical populations, such as elderly patients and ‘triple-low’ patients. Furthermore, efforts have been made to optimize the clinical application of perioperative acupuncture.

Key words: acupuncture; anaesthesia; general; postoperative complications

Editor’s key-points

• The authors provide an evidence-based review of the potential contribution of acupuncture to perioperative medicine and anaesthesia.

History

The history of perioperative acupuncture dates back to August 30, 1958 in Shanghai First People’s Hospital, Shanghai, China. A tonsillectomy was completed under acupuncture without any other anaesthetics by Dr. Xinliang Zhuang, an anaesthetist, and Dr. Huizhu Yin, an ENT doctor. From that time, acupuncture was believed by some practitioners to be able to induce anaesthesia for surgeries, including appendectomy, cholecystectomy and Caesarean section. This technique was then named ‘Acupuncture Anaesthesia’ and was in vogue for a time in the 1970s (See Supplementary Digital Content 1, which shows surgeries completed under acupuncture anaesthesia in the 1970s in China). It was even depicted on a Chinese stamp issued in 1975, as part of a set of four stamps to commemorate the successful integration of traditional Chinese medicine (TCM) and modern Western medicine in the treatment of various diseases.2

Then, more practitioners realised that acupuncture itself was not able to provide adequate anaesthesia for surgery but reduced...
the demand for narcotics or anaesthetics. The term ‘Acupuncture Anaesthesia’ was therefore replaced with ‘Acupuncture Assisted Anaesthesia’. Generally, when anaesthetists incorporate acupuncture into anaesthetic techniques, it enhances the sedative and analgesic effects of pharmaceuticals. In many publications the term ‘Combined Acupuncture-drug Anaesthesia’ was used as well.3,4 However, accumulated evidences have demonstrated that acupuncture reduces not only anaesthetic consumption but also perioperative complications. It helps to modulate homeostasis, improve organ function, and keep the body in a balanced state perioperatively. Therefore, we suggest the term ‘Perioperative Acupuncture Modulation’ to better describe the role of acupuncture during the perioperative period.

The role of acupuncture during the perioperative period

Perioperative acupuncture provides clinically meaningful benefits for patients. It helps to reduce consumption of anaesthetics and analgesics, and to reduce the complications, including postoperative nausea and vomiting (PONV), haemodynamic instability and intubation-related complications. Furthermore, the organ-protective effect of acupuncture supports its application perioperatively.

Acupuncture reduces the consumption of anaesthetics and analgesics

Acupuncture itself does not provide adequate anaesthesia nor a sufficient state of unconsciousness, and during procedures, patients usually need to be soothed. However, after it was first reported in 1981 that electro-acupuncture (EA) reduced halothane requirements, researchers started to notice the effect of acupuncture and related techniques on a reduced consumption of anaesthetics or analgesics (See Supplemental Digital Content 2, which lists clinical studies on acupuncture and anaesthetic/analgesic consumption). This effect could be clinically important because higher doses are generally related to higher risks of morbidity, longer durations of recovery and higher cost.

Inhaled anaesthetics

The effect of acupuncture on reducing the consumption of inhaled anaesthetics has been demonstrated in animal, volunteer and patient studies. In parallel with the earliest report by Tseng and colleagues in dogs, early studies were mostly on the halothane-reducing effect. With the development of inhaled anaesthetics, the effect of acupuncture on the demand for volatile anaesthetics, such as sevoflurane and desflurane, has been widely investigated.5–8 In healthy volunteers, acupuncture led to an 8.5–11% decrease in the desflurane requirement to prevent noxious stimulation.6,7 However, controversial results, such as an increased demand for sevoflurane (MAC from 1.8 to 2.1%), have also been reported.8 Details of these studies are summarized in Supplemental Digital Content 2. Other factors, including acupuncture point selection and the timing of stimulation, may contribute to the varying effects of acupuncture. However, the small sample sizes of these studies (N=46 at the most) limited their power to provide strong evidence.

Opioids

Opioids are often considered necessary for the induction and maintenance of anaesthesia. Early studies on opioid-sparing effects of acupuncture took place in the 1990s and focused on fentanyl. The effects of acupuncture on the demand for remifentanil, alfentanil and sufentanil have been investigated mostly in the last two decades. Acupuncture was able to provide the same analgesic effect as alfentanil during minor procedures, such as oocyte aspiration.10,11 In minor surgeries, such as a sinusotomy, transcutaneous electric acupoint stimulation (TEAS) decreased remifentanil consumption by 39%.12 In major procedures, such as open heart surgery under cardiopulmonary bypass,13 patients in the combined acupuncture-drug group required only 13% of the total dose of fentanyl required in the general anaesthesia group.

Hypnotics

Acupuncture has been used to treat insomnia, and it was demonstrated to influence the A-line ARX Index (AAI) in un-sedated adult volunteers. An important role of acupuncture during the...
perioperative period is to provide relaxation and sedation. Acupuncture on special acupoints significantly reduced stress levels, and even caused significant relaxation and drowsiness. During surgery and in intensive care units, acupuncture could decrease the need for hypnotics, including propofol and midazolam. In patients who received a target controlled infusion of propofol for general anaesthesia, TEAS could decrease the propofol dosage by up to 27%. The decreased dose of hypnotics leads patients to a shorter stay in the recovery room and shorter time to extubation. Also EA markedly reduces the dose of midazolam required in critically ill patients with mechanical ventilation monitored by BIS. The sedative effect of acupuncture may also help to alleviate the intensity of postoperative pain and reduce the consumption of postoperative analgesics because of the close relationship among sedative effects, pain and analgesics. However, it should be emphasized that acupuncture does not affect motor function and normal sensory perception during surgery, in contrast to ‘true anaesthesia’.

Other anaesthetics
Both acupuncture and EA prolong the anaesthetic effect of the ketamine-xylazine combination in rats, allowing a longer duration of anaesthesia with a lower dose of anaesthetic. Rosted and colleagues observed that the onset of a local anaesthetic was quicker if segmentally administered acupuncture was given before a regional inferior dental block. The faster onset of local anaesthetics may be as a result of increased local blood flow after acupuncture.

Acupuncture reduces anaesthesia-related adverse effects
Postoperative nausea and vomiting (PONV)
PONV is a common complaint after surgical anaesthesia, with an incidence of up to 70%. It can have a tremendous impact on surgical outcomes and is often rated by patients as worse than post-operative pain. PONV is on the list of medical conditions that may benefit from treatment with acupuncture, issued by the World Health Organization. The P6 acupoint is one of the most commonly used and well investigated acupoints for PONV prophylaxis and treatment. Stimulation at P6 could be a non-pharmacological alternative to antiemetics, such as ondansetron, droperidol and metoclopramide. The efficacy of this non-pharmacological procedure approached great interest and initiated numerous clinical studies (see Supplemental Digital Content 3, which lists clinical studies on acupuncture and PONV). A systematic review of the effect of stimulating P6 on PONV was published in the Cochrane Database of Systematic Reviews in 2004 and was updated in 2009; both presented positive conclusions. In 2013, based on a meta-analysis, Cheong demonstrated that in addition to PC6 alone, PC6 combined with other acupoints and alternative acupoints could be beneficial in the prevention and treatment of PONV. The alternative acupoints include LI4, ST36, and auricular acupoints. Many of the studies were placebo-controlled clinical trials, thereby excluding the placebo effect to some extent. Compared with vomiting, acupuncture seems to be more effective in controlling nausea. In some studies, acupuncture failed to elicit antiemetic effects. The reasons for this discrepancy may include different timing and intensity of stimulation, which will be discussed below.

Some studies using relatively mild techniques, such as acupuncture, reported negative results. This suggests that the stimulation needs to be sufficiently strong to initiate the beneficial effects. Additionally, to be effective, acupuncture should be given before opioids or its effect can be abolished by local anaesthesia. A meta-analysis published in 1999 reported negative results in children regarding the acupuncture-induced antiemetic effect. However, later studies demonstrated the efficacy of acupuncture for PONV in the paediatric population, and in a 2009 review by Lee, acupuncture for PONV was concluded to be effective in the paediatric population.

The mechanism underlying acupuncture’s ability to reduce PONV is still being explored. Changes in serotonin transmission and beta-endorphin release may play a role. Local anaesthesia of the P6 area was able to block the antiemetic effect of acupuncture at the P6 acupoint, supporting the hypothesis that nerve transduction plays a role.

Haemodynamic instability
The effect of acupuncture on blood pressure provides a clear example of why the word ‘modulation’ is used to describe the role of perioperative acupuncture. Acupuncture and related techniques help the sympathetic nervous system maintain the balance that the body needs, to recover from pathophysiologic changes. It has both anti-hypotensive and anti-hypertensive effects. Acupuncture lowers blood pressure in patients with hypertension while elevating it in those with hypotension. Its effect depends on the selected acupuncture protocols. In both parturients and patients undergoing inguinal hernia repair, transcutaneous electric nerve stimulation (TENS) at PC 5 and PC 6 had been demonstrated to significantly alleviate hypotension after neuraxial anaesthesia. In patients with end-stage liver diseases that underwent liver transplantation, EA at PC 6 and PC 5 had the same anti-hypotensive effect as a norepinephrine infusion, indicating that the modulation of sympathetic tone plays an important role. In these anti-hypotension studies, high-frequency stimulation (e.g. 50 Hz) was commonly used. Conversely, a low-frequency EA should be chosen to induce an anti-hypertensive effect. Suppression of the stress response during surgery, indicated by a smaller increase in cortisone, is another beneficial aspect of acupuncture for haemodynamic stability. The relationship between frequency and effect will be discussed below. Some investigators used transcutaneous electrical stimulation of ST36, combined with a nitro-glycerine infusion to facilitate a reduction in blood pressure. They achieved a 6 mm Hg blood pressure decrease compared with the sham group and successfully produced a bloodless surgical field, which provided an alternative method for controlling hypotension.

Other complications
Intubation can lead to a postoperative sore throat. Gentle and skilful intubation may not eliminate it. Acupuncture has demonstrated potential in the prevention and treatment of postoperative intubation-related sore throats. Of the 114 patients in the acupuncture group, 16 (14%) experienced sore throats within the first 24h postoperatively, which was significantly lower than the 34 patients (29.8%) in the control group. The results achieved were questionable regarding acupuncture’s effect on post-extubation laryngospasm. One acupuncture technique (i.e. bloodletting acupuncture at LU 11, LI 1 or both) even demonstrated a negative effect. Hence, the currently available data do not support the use of acupuncture as a prophylaxis during extubation.

Acupuncture may alleviate the stress response by balancing the sympathetic tone. EA at ST36 and SP6 for 30 min before induction prevented hyperglycaemia during anaesthesia, and the increased levels of cortisone and increased sensitivity to insulin were attenuated.
Patients with some refractory complications may choose acupuncture as a potentially effective and non-invasive therapy. Dietzel and colleagues\textsuperscript{53} found that acupuncture is effective in treating post-dural puncture headache. The combination of stimulating BL2, BL10, BL60, BL62, GB20, LI4, LR3, SI3 and auricular acupoints helped the patients return to normal daily activities and shortened the duration of hospitalization. These results support two previous case studies\textsuperscript{54, 55} and indicate that acupuncture is an effective method for treating post-puncture headache. Another troublesome complication, persistent postoperative hiccup, could also be alleviated by acupuncture,\textsuperscript{56} and this effect was confirmed by Lin and colleagues in a heart and lung transplant recipient.\textsuperscript{57}

**Acupuncture enhances postoperative analgesia**

The initial global interest in acupuncture stemmed from a report regarding James Reston, a New York Times reporter, who experienced acute appendicitis during President Nixon’s trip to Peking in 1971. His postoperative pain was treated with acupuncture. Today, pain is among the specific conditions for which acupuncture’s efficacy is well accepted, according to a statement issued by the NIH,\textsuperscript{58} and postoperative pain is an issue of interest in the field of perioperative acupuncture (See Supplemental Digital Content 4, which lists clinical studies on acupuncture and postoperative analgesia). Reviews are continually updated.\textsuperscript{59-64}

Clinicians are primarily concerned with the duration and intensity of acupuncture-induced postoperative analgesia. Depending on the study design, controversial results have been reported. Some researchers argue that the analgesic effect of acupuncture is moderate and may not be clinically relevant. However, a review by Sun and colleagues,\textsuperscript{65} which included fifteen RCTs conducted up to 2008, revealed a 21–29% reduction in opioid consumption after acupuncture, which is generally considered to be clinically significant. The conclusion of this review has been supported by recent studies.\textsuperscript{23, 66-70}

Questionable results have been achieved regarding the duration of acupuncture analgesia. In Sun’s study, the analgesic effect of acupuncture increased with time. However, the analgesic effect of a single session of EA may last only two to three h and could have been masked by high doses of opioids in some studies.\textsuperscript{67} Furthermore, acupuncture decreases not only the consumption of opioids but also the incidence of morphine-related side-effects, including nausea and vomiting, itchiness, gastrointestinal disorders, pruritus, dizziness, sedation, and urinary retention.\textsuperscript{68} The reduction in side-effects can be explained by the decreased dose of opioids or can be attributed to the acupuncture itself. Acupuncture provides an alternative for patients with a limited ability to use adjunct analgesics, such as nonsteroidal anti-inflammatory drugs, because of concerns regarding adverse effects, such as bleeding and renal dysfunction.

Postoperative analgesia from perioperative acupuncture seems not to be limited by the anaesthetic technique. In surgical patients undergoing local anaesthesia, acupuncture was also demonstrated to alleviate postoperative pain. In patients undergoing inguinal hernia repair, the EA group reported less pain and lower consumption of analgesics.\textsuperscript{71} The efficacy of acupuncture with respect to postoperative analgesic consumption and pain scores after oral surgery has been reported as well.\textsuperscript{72} The pain-free postoperative time increased from 94 min to 173 min as a result of the use of acupuncture.

The mechanism behind acupuncture-induced analgesia has long been explored, and there has been a significant increase in the number of articles published each year. Endorphin hypothesis of acupuncture was introduced in 1976. Recent developments, especially in imaging studies, have provided knowledge on the basis of acupuncture-induced analgesia.\textsuperscript{73, 74} Magnetic resonance imaging (MRI) and positron emission tomographic (PET) scanning have helped researchers to further understand the anatomic basis and cerebral projection of acupuncture.

Acupuncture protects vital organs (see Supplemental Digital Content 5, which lists clinical studies on acupuncture and organ function).

**Heart**

Results of both animal and clinical studies have demonstrated the modulatory effects of acupuncture on the heart. Acupuncture on Jen Chung (GV 26) significantly increased cardiac output, stroke volume, heart rate, mean arterial pressure, and pulse pressure, while it simultaneously significantly decreased total peripheral resistance and central venous pressure. It was suggested that the stimulation of the GV 26 acupoint could be helpful in resuscitating patients, whose cardiovascular system is depressed by opioids and volatile anaesthetics.\textsuperscript{75} Additionally, by improving haemodynamic stability, acupuncture helps to improve cardiac outcome as well. We performed a RCT to address the protective effects of EA pre-treatment on myocardial injury, in patients undergoing heart valve replacement surgery.\textsuperscript{76} After EA at bilateral PC6, LU7, and LU2, overall serum troponin I release and the inotrope score decreased, as did the duration of the patients’ stay in the intensive care unit. We also observed that in paediatric patients,\textsuperscript{77} mean cTnI levels were significantly lower in a TEAS group after aortic unclamping. The duration of ventilation and length of ICU stay were significantly shortened as well. Shen and colleagues\textsuperscript{78} observed an effect of acupuncture on cardiac function, in patients undergoing orthopaedic surgery and found a decrease in ST elevation. The cardiac protective effect of acupuncture may be meaningful in specific populations, such as those with coronary artery diseases or cardiac dysfunction, improving outcomes after cardiac or non-cardiac surgery.

**Lungs**

Acupuncture protects the lungs against perioperative injuries and is beneficial in improving postoperative pulmonary function. The effects could result from a decreased use of anesthetics or direct mechanisms. In rats, EA at BL13 and BL15 has been demonstrated to protect against hypoxia-induced pulmonary hypertension, possibly by regulating the balance of endothelium-derived vasoconstrictors and vasodilators.\textsuperscript{80} Transcutaneous auricular vagus stimulation and ST36 stimulation may suppress LPS-induced high TNF-α levels and NF-κB signals in lung tissue.\textsuperscript{81} Acupuncture may induce bronchial dilation in asthma patients.\textsuperscript{82} In patients undergoing open heart surgery or lung resection, acupuncture increases the forced vital capacity after surgery, indicating a better pulmonary function.\textsuperscript{83-85}

**Brain**

Acupuncture has been demonstrated to protect against brain ischemia in animals. It helps alleviate brain oedema and improve perfusion of the penumbra. We have demonstrated that, in patients undergoing crano-cerebral tumour resection, TEAS at LI4 and ST36 decreased the level of NSE and S100β, serum biomarkers of brain damage.\textsuperscript{84} Patients undergoing surgeries who are at an increased risk of brain hypoperfusion may benefit from perioperative acupuncture. Researchers have observed up to 35.86% shorter times to autonomous respiration recovery, extubation, eye-opening, voluntary motor recovery, orientation, and
dearth from the operating-room in patients undergoing cranio­tomies.85

Liver and kidneys
During surgery, the blood flow in the liver and kidneys may be af­fected by various factors, including pneumoperitoneal pro­cedures and hypotension. Animal studies have indicated that acupuncture was able to alleviate the adverse effects caused by these pathophysiological changes. In anaesthetized rats, even a single 30-min 10/100 Hz EA session could enhance lipid peroxida­tion and simultaneously reduce oxidative stress in liver and kid­ney tissue.86 EA increases the mean blood flow or perfusion in the liver as well,87 which may be a benefit to patients undergoing lap­aroscopic procedures. In endotoxaemic rats, EA at PC6 signifi­cantly attenuated elevated biochemical markers of liver and renal injury, markedly decreased the infiltration of neutrophils into liver tissues caused by LPS, and reduced the renal histo­pathological score.88 89 ST36, PC6, SP9 and LR8 are all candidate acupoints for hepatic and renal protection. Although there are limited results from human studies, acupuncture is promising for inducing the protection of hepatic and renal function through increased blood flow and the modulation of inflammatory mechanisms.

Gastrointestinal protection
Gastrointestinal function can be impaired by surgical or anaes­thetic interventions, such as opioid administration.90 Intraopera­tive and postoperative acupuncture for pain relief decreases perioperative opioid consumption and may thus indirectly speed up postoperative recovery of intestinal function. The stimulation of ST36, combined with auricular-plaster therapy, can improve intestinal function during the early stages of recov­ery after surgery.91 The percentage of patients who exhibited full recovery of normal peristalsis increased from 46 to 92.4%. Studies on postoperative acupuncture are limited by small sample sizes (i.e. N between 26 and 60).92 93

How to optimize perioperative acupuncture modula­tion

Acupoint specificity and selection
The acupoints and modes used for stimulation may significantly affect the outcome of acupuncture for blood pressure modula­tion, PONV prophylaxis, and postoperative pain relief. Inapprop­riate acupoints may lead to negative or even opposite results. There are certain rules and principles that are generally applied when selecting acupoints for acupuncture treatment. First, an appropriate meridian should be selected, and appropriate points on these meridians should be stimulated. For example, for post­operative pain control, a meridian that passes through or close to the surgical area is usually selected. Additionally, according to TCM theory, the lung commands the skin. Consequently, the stimulation of acupoints on the lung meridian can provide anal­gesia for surgical skin incisions. Based on the theory of meridian and evidence from previous studies, the selection of acupoints for various surgeries are summarized in Table 1. The combi­nation of acupoints is also important. The acupoints selected can be on the same meridian or different meridians.93 Diff­erent components of postoperative pain seem to respond to different combinations of acupoints.

The De-Qi response is another criterion for acupoint selec­tion. The needling of points that easily produce a strong De-Qi sensation is thought to provide better efficacy. Reactive points

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<th>Table 1 Acupoints frequently selected for specific surgeries</th>
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that are commonly selected include ST36, SP6, LI4 and P6. When selecting acupuncture points, one must consider conveni­ence and the comfort of patient. Points located below the knee or elbow are usually selected during surgery.

In some studies, non-acupoint stimulation exhibited efficacy as well. For example, some researchers questioned the role of acupoints because TENS near the incision site also significantly reduces postoperative pain. However, TENS near the incision site mainly stimulates specific afferent nerve fibres,108 instead of triggering endogenous opioid-release mechanisms. Further­more, if the subject is not blinded to the intervention, a placebo effect in the non-acupoint group may exist, which can partially explain the positive results in the non-acupoint group.

Techniques used to stimulate acupoints
Numerous methods to stimulate acupoints have been developed (see Supplemental Digital Content 6, which shows some acu­puncture-related techniques). The stimulation techniques can be roughly divided into invasive and non-invasive methods. The optimal method of stimulation has not yet been identified. Non-invasive methods are more acceptable to patients and incur less risk of infection or bleeding. However, the debate on the efficacy of acupuncture’s electrical equivalents, EA and TEAS, continues. According to TCM theory and a systematic review,111 a strong De-Qi sensation indicates a good response to acupuncture. Both manual and electric stimulation techniques can achieve the De-Qi sensation. Studies have even suggested that electrical stimulation provides better analgesia;75 additionally, it does not require practitioners to spend as much time with the patient and is easier to standardize.

The mechanisms behind different stimulation techniques may be different. It was reported that manual acupuncture manipulations decreased MRI signals, in contrast to EA stimulation, which generally increases MRI signal intensity,112 and EA pro­duces more widespread fMRI signal changes than manual acu­puncture stimulation.113 Various stimulation modalities thus
appear to trigger different brain networks depending on how acupuncture is stimulated.

For EA, electrical modalities, including frequency and intensity, are important factors influencing its effect. Different frequencies may induce different effects. In rats, Liao and colleagues demonstrated that low frequency EA stimulation activates sympathetic vasomotor tone, whereas high frequency causes additional potentiation of the sympathetic drive to the heart. Low-frequency stimulation produced analgesia of slower onset but longer duration, (i.e. lasting many hours). In contrast, high-frequency stimulation resulted in more rapid onset of analgesia but with a shorter duration.

Low-frequency (i.e. 2–4 Hz) stimulation resulted in the release of enkephalin, β-endorphin and endomorphin and was mediated by both mu- and delta-opioid receptors, while high-frequency (e.g. 50 Hz) stimulation involved the release of dynorphin and was mediated by kappa receptors. Medium-frequency (e.g. 30 Hz) stimulation induced anti-nociception mediated by all three opioid receptor types. Non-opioid mechanisms, such as noradrenergic and muscarinic mechanisms, are also involved in the process of EA. The analgesia intensity of 2 Hz EA depends on noradrenergic and muscarinic mechanisms; in contrast, the intensity of 100 Hz EA involves spinal muscarinic and GABAB mechanisms. Genes that are more closely related to neural function, including synaptic transmission, behaviour and morphology, were down-regulated by 2 Hz EA in both DH and PAG regions compared with 100 Hz EA. Furthermore, different frequencies of EA stimulation may activate different brain areas, according to fMRI studies.

**Timing of stimulation**

Based on TCM theory, the onset of acupuncture’s effect is 15–30 min, and acupuncture during anaesthesia may not be comparable with that in conscious patients. Anaesthetics, such as propofol, reduce the neurophysiological response to acupuncture stimulation as measured by acupuncture-induced blood oxygenation level-dependent signals. It is important to establish the right acupuncture point using the De-Qi sensation to enhance efficacy. Previous studies in which acupuncture was started after the induction of anaesthesia, revealed reduced efficacy, or a lack of efficacy, although the mechanism underlying this phenomenon is not known. Vickers reviewed 33 controlled trials in which the P6 acupoint was stimulated for treatment of nausea and vomiting. They found that the acupuncture of P6 was equal or inferior to the control in all studies, when acupuncture was started after the induction of anaesthesia. This has prompted an ongoing debate regarding the importance of starting acupuncture before the induction of general anaesthesia. A similar debate exists regarding studies on the effects of acupuncture on analgesic consumption. In Kverning’s studies, the EA group needed more sevoflurane than the control, when EA was started after induction. A meta-analysis of 24 trials on acupuncture-induced analgesia, has indicated that only preoperative acupuncture had a statistically significant opioid-reducing effect. However, this result should be interpreted with caution because only three studies were included in the postoperative group. More well-designed RCTs are needed to establish the optimal timing for the acupuncture administration and the ideal duration of stimulation.

**Perspectives**

The beneficial effects of perioperative acupuncture may be clinically significant, especially in specific surgical populations. First, we considered the outpatient surgery population. There has been an increasing emphasis on ambulatory anaesthesia, and the use of more than one modality to achieve satisfactory anaesthetic and analgesic effects, while reducing related side-effects, has become the cornerstone of enhanced recovery. Given the benefits of perioperative acupuncture on anaesthetic requirements, anaesthesia-related complications and organ function, it should be considered as an alternative in the Enhanced Recovery After Surgery (ERAS) programme. For example, opioids are the mainstays of most analgesia regimens during and after surgery, but their dose-related side-effects can occur as frequently as 12.2% of the time, which delays recovery after ambulatory anaesthesia, incurs higher costs (i.e. $22,077 USD vs $17,370 USD), leads to longer length of stay (i.e. 7.6 vs 4.2 days) and increases readmission rates [odds ratio (OR) 1.06, 95% confidence interval (CI) 1.02–1.09]. By reducing the dose of opioids needed for analgesia by 39–87% and the dose for postoperative analgesia by 21–29%, perioperative acupuncture promises to improve ERAS. The low cost and low incidence of adverse effects with this technique also satisfy the call for cost-effectiveness.

The elderly population, who suffer a higher incidence of postoperative morbidity and mortality, would greatly benefit from perioperative acupuncture. Even when using lung protective ventilation strategies, early pulmonary complications develop in 17.5% of patients (36% in patients without non-protective strategies). Opioid-induced respiratory depression, pain, ileus, sedation and immobility because of PONV all contribute to morbidity. Perioperative acupuncture may be an optimal choice for these patients. We observed the protective effect of TEAS on pulmonary morbidity after gastrointestinal surgeries in elderly patients (unpublished data, Clinicaltrial.gov ID: NCT02239159). Multicentre RCTs together with other high quality RCTs suggest a clear clinical value of perioperative acupuncture. Further study is warranted to evaluate the effect of perioperative acupuncture on long-term outcomes after surgery.

Patients demonstrating the ‘triple low’ effect, belong to another population that may benefit from perioperative acupuncture. The phenomenon investigators have dubbed ‘triple low,’ a combination of low volatile minimum alveolar concentration (MAC) equivalents, low blood pressure, and low bispectral index values (BIS), is associated with increased postoperative mortality and prolonged hospital stays. Future research efforts regarding the effect of perioperative acupuncture will assess its value in this population.

Efforts have been aimed at maximizing the benefits of perioperative acupuncture in the abovementioned populations. Traditional manual acupuncture requires a well-trained practitioner. Acupuncture-related techniques, including EA and TEAS, are easier to execute. Special devices (e.g. a cunometer) could be used for better point location. Standard protocols for acupoint selection for specific surgeries and populations may help reduce confusion, and the installation of automated or semi-automated instruments that perform these protocols will make the practice more standardized. Once these instruments are commercially available, the practice of perioperative acupuncture will be greatly changed.

The further exploration of the mechanisms underlying acupuncture is crucial to answer many questions regarding perioperative acupuncture modulation. For example, given the knowledge that low-frequency EA increased vagal activity, whereas high-frequency EA enhanced sympathetic activity, the latter would be a better choice for treating hypotension, and this has been verified. The recent finding that reactive oxygen species, homeostasis and endocannabinoids were...
involved in the process of acupuncture provided evidence for the organ protective effects of acupuncture as well. Additionally, the introduction of functional neuroimaging, including fMRI and PET, has helped reveal the relationship between acupuncture and specific brain areas. The haemodynamic-based fMRI is a non-invasive neuroimaging method, with good spatial resolution and adequate temporal resolution. It can estimate activity anywhere in the brain, every few seconds and detectchanges in brain regions related to acupuncture almost simultaneously. Coupling neuroimaging with longitudinal clinical evaluation has been used to explore the sedative and analgesic effects of acupuncture. Future studies will continuously benefit from these techniques.

In conclusion, the role of perioperative acupuncture extends far beyond anaesthesia and benefits patients during the entire perioperative period. Perioperative acupuncture is promising to be of great value in improving the patients’ short-term and long-term outcomes. Although there are difficulties associated with assessing the role of acupuncture during the perioperative period, well-designed RCTs, standard protocols for practice and a better knowledge of the underlying mechanism, will pave the way for future applications of perioperative acupuncture modulation.

Declaration of interest
None declared.

Funding
This work was supported by National Key Basic Research Program of China (No. 2014CB543200).

Authors’ contributions
Study design/planning: Z.L., Q.W., H.D., L.X.
Study conduct: Z.L.
Writing paper: Z.L., Q.W., H.D., L.X.
Revising paper: Z.L., Q.W., H.D., L.X.

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Handling editor: J. G. Hardman