Abstract: The use of regional anesthesia techniques for intra-operative anesthesia remains very controversial for patients scheduled to undergo spinal interventions. Spine surgery is still mostly performed under general anesthesia. This has to be explained by the patient’s position required during surgery, the extent and duration of some procedures, the preference of the surgeon and/or anesthesiologist and a trend which becomes more and more prominent to abandon central nerve blocks in general. The presence of foreign material in the neighborhood of the surgical field may be a reason for surgeons to refuse such techniques. Nevertheless, during the last decade the available literature has increased progressively in support of regional anesthesia for these interventions. The present overview will focus on the feasibility of different regional techniques to be used intra-operatively. These techniques may also be of interest or even intended for prolonged postoperative analgesia and benefit even after a single bolus injection, continuous or intermittent administration. Although all techniques described offered favorable success rates, future research is mandatory to determine their superiority over general intra-operative anesthesia and conventional pain therapy.

Key words: Anesthesia; analgesia; regional; spinal; epidural; surgery; lumbar; spine.

Introduction

The most common used technique to anesthetize patients scheduled for thoracic or lumbar spine surgery is still general anesthesia. However several benefits of regional anesthesia (RA) over general anesthesia (GA) have been suggested for spine surgery (1). Nevertheless, it is rarely used due to lower acceptance by patients, the ability to easily extend the duration of an operation in case of general anesthesia, and/or the anesthesiologist preference for general anesthesia because of a secure airway establishment prior to placement of the patient in the prone position (2). With the actual trend to abandon central nerve blocks, the interest in regional anesthesia for this type of surgery will surely not be stimulated. Nevertheless, of the 24 found publications dealing with intra-operative regional anesthesia for spine surgery, only 5 studies were published before 2002, while, surprisingly, only 7 were published in anesthesia journals. As a consequence, several specific details with respect to the anesthetic technique may be lacking.

Spinal, epidural or even caudal approaches may be combined with general anesthesia, but such a combination will be mostly chosen when postoperative analgesia is the focus.

When reviewing the literature, making straightforward conclusions is disabled by the variability in the extent of the surgical type, the design of the study (retro- or prospective, cohort, case control, randomized…), different regional techniques used alone or in combination with general anesthesia, selected drugs, combinations of them, age of the patient groups, and selected outcome parameter.

A recent review on eleven studies comparing endotracheal anesthesia with spinal-based regional anesthesia, containing 4 randomized trials, 3 case control trials, 2 prospective cohorts, and 2 retrospective analysis found a majority of studies reporting reduced heart rates and mean arterial pressures in the RA cohorts, and lower incidence of postoperative pain and/or requirement for analgesics (3).

We here intend to give a complete, comprehensive review including all studies comparing RA with GA, different RA techniques, local anesthetics or the effect of different positions on outcome parameters after spine surgery. Only those studies were included where the main focus was upon intra-operative conditions and where injections were given or catheters introduced at the induction of
anesthesia, while not during the course of surgery, pre-closure or postoperatively.

**SPECIFIC ADVANTAGES OVER GENERAL ANESTHESIA**

Advantages with respect to intra-operative and early postoperative conditions may be different for spinal (1, 2, 4-11) or epidural (12-18) anesthesia.

The procedural and/or anesthesia time may be shorter than in case of general anesthesia, mostly because of a shorter interval between the anesthetic induction and incision (depending on the selected RA technique) but also following wound closure (7-11). During the surgical procedure itself, less blood loss may also shorten surgical time, although, due to the limited blood loss in general, statistical significance may not always be obtained (11). A cleaner operative field may be explained by either spontaneous breathing of the patient, causing lower intra-thoracic pressure with subsequent less distention of the epidural veins, or otherwise the induction of hypotension and vasodilatation due to the sympathetic block. Despite common occurrence of some degree of hypotension, it was found that hemodynamic stability may be better maintained with somewhat lower heart rates and blood pressures than in patients under GA, possibly due to inhibited release of stress hormones, glucose, and interleukins intra-operatively (1, 4-7, 11, 17).

The occurrence of hypotension will depend on the position of the patient during surgery. With the knee-chest position, hypotension, whether intended or not, will be more pronounced as blood will be pooled in the pending lower extremities. As patients may be operated in lateral or sitting position, this may also reduce the presence of blood in the operative field, due to orthostatic drainage of blood (15). However, on the other hand, orthostatic pressure upon veins and CSF as in the sitting position, may also enhance the risk of bleeding and the occurrence of a dural tear in other than prone positions (15). Nevertheless, following spinal anesthesia for back surgery, the incidence of postdural puncture headache seems to be extremely low. It may be speculated that surgical bleeding in the area of the dural puncture site may function as a blood patch. Some studies even found that spinal anesthesia resulted in less spinal headache as compared to general anesthesia (7, 8).

A reduction in thrombo-embolic complications has also been reported in patients receiving spinal anesthesia for back surgery, most probably related to either faster mobility and/or modulation of the hypercoagulable state that occurs and persists after major surgery (5). Neuraxial anesthesia with local anesthetics (LA) is known to enhance fibrinolytic activity, reduce antithrombin III activity to normal levels, and attenuate increases in postoperative platelet activity.

Patients operated under regional anesthesia may experience less nausea and emesis. This is likely related to intra-operative anesthetic factors. RA may be supplemented with intravenous propofol sedation, as done in some studies, while having itself antiemetic properties. In addition, RA is associated with improved gastric emptying, leading to decreased nausea and vomiting as well (4, 5, 7-9, 12, 14, 17).

Another benefit of regional anesthesia is the ability of the patient to self position. Being awake or, at the most slightly, sedated, this may prevent complications related to malpositioning of the head, eyes, and upper extremity, and resulting in blindness, brachial plexus pathology, or pressure sores.

Although urinary retention is commonly considered to be a problem after all central nerve blocks, mostly due to the local anesthetic and/or opioid effect, others found the incidence after spine surgery to be similar among patients operated under GA or spinal anesthesia (without intrathecal opioids) or according to some studies even more frequent with GA (4, 6-8).

In the postoperative phase, neuraxial anesthesia techniques even consisting of one single bolus administration may cause lower intra-operative opioid requirements if combined with general anesthesia, lower postoperative pain scores, and/or analgesic requirement, with additional benefit with respect to the incidence of nausea, vomiting, or need for anti-emetic medication in the postoperative period (1, 4, 9, 11-14, 17, 18).

When a catheter is present to supplement intra-operative anesthesia, this may either be used postoperatively, or, when not intended to be used after surgery, it can be withdrawn after a final injection to prolong the duration of analgesia or the interval till a first request for rescue analgesia. Initiation of a regional technique before the surgical incision may suggest a pre-emptive analgesic effect as well. Not infrequently the term ‘pre-emptive’ has been used for postoperative analgesia, although the neuraxial substance was given after incision in case of a combined general-neuraxial technique, or locally, immediately after neural root exposure. Even a better effect than placebo when administering substances before incision does not prove a ‘pre-emptive’ effect.
Although not commonly reported, neuraxial blocks may result in faster food intake, ambulation, shorter hospital or PACU stay and lower costs (6, 7, 11, 17). Patient and surgical satisfaction may also be higher when surgery is performed under RA, though only reported following spinal anesthesia (1, 6).

Possible Concerns with Regional Techniques

Not all reports are in favor of spinal or epidural anesthesia. The above mentioned advantages are not supported by all authors.

When using epidural anesthesia, which is more time-consuming but longer-lasting than a single dose spinal, no difference may found in procedure time or time of mobilization out of bed when compared with general anesthesia (14). Few studies found longer operation room time or surgical time, but equal total anesthesia or procedural time when compared with general anesthesia (12, 16).

Depending on the discharge criteria, there may be no differences between GA and RA in terms of length of stay in the hospital, while PACU times may even be prolonged after regional anesthesia, especially when LA with a long duration of action have been used and discharge is allowed after sensory and motor block recovery, or hemodynamic parameters are restored. (4, 9, 12, 14, 16).

Sadrolsadat et al (2) contested that SA would have advantages over GA. They found that GA causes less intra-operative bleeding, but also higher satisfactory conditions for the surgeon and the patient. In addition, total intravenous anesthesia with propofol in these operations may reduce the incidence of nausea and vomiting. However, hypertension was more frequent during the recovery period, which confirms the findings of other studies (4, 11, 12, 18).

When patients are operated for spinal stenosis or herniated disc with compromise of the available space within the spinal canal, there is a risk of cauda equina syndrome with any additional space occupying volume, be it blood, abscess formation, or injected fluid such as a local anesthetic when the selected epidural bolus dose or hourly infusion is too large. Some non-neurosurgical cases have been reported where the neuraxial block was considered to be responsible for the presentation of acute symptoms (19-22). For some reason, combined spinal-epidural anesthesia was more often the culprit technique than epidural or spinal anesthesia alone.

With respect to herniated disc, posterior displacement, although extremely rare but nevertheless already reported in over 20 cases, may increase the risk of cauda equina, necessitating emergency surgery (23-28). Pregnancy may also predispose patients to develop these symptoms in case of a herniated disc, which has been described in more than 10 cases and during all trimesters of pregnancy, even following Caesarean section (29-34). Cauda equina symptoms have been described in patients scheduled for other types of surgery, in which the existence of a spinal stenosis was unknown. It is far from clear whether, when operated for spine problems, dand espite laminectomy of herniated disc surgery, patients are less at risk after than before their surgery. Spinal anesthesia, on the other hand, may be a better alternative, although, when performed below the lesion, optimal spread may be obliterated with possible block failure or neural toxicity due to accumulation.

Cooperation of the surgeons is highly desirable but, quite often, they may be reluctant to allow the presence of foreign material close to the surgical field, fearing infection. In addition, they want to evaluate the neurological function post-surgery. Local anesthetics with a long duration of action or continued use of catheters for the treatment of postoperative pain may prevent them to observe the appearance of complications such as spinal hematomyoma formation (35, 36). As a consequence, post-operative analgesia, when using local anesthetics, is commonly initiated once certainty is obtained about normal neurological function.

Patients operated for spine surgery are often supposed to stay in bed in the supine position for at least 24 hours or longer. The most embarrassing problem for these patients may be difficulty to void in the supine position. Neuraxial techniques may further affect the detrusor reflex or the urge to void, for which local anesthetics, opioids, or both may be responsible. The impact of other adjuvant substances upon micturition is less clear. This may require placement of a temporary bladder catheter, which itself may cause urinary infection while lowering widespread acceptance of RA by patients, nursing staff, surgeons, and anesthetists. Nevertheless, depending on the type of surgery, placement of a urinary catheter before the surgical incision may be routine practice in some hospitals.

Despite the theoretical advantage of continued benefit in the postoperative period, either related to the anesthetic bolus or catheter use, neuraxial analgesia has also been refuted as the optimal analgesia technique because of increased costs, high
failure rate due to catheter loss in up to the 37%, more side-effects (pruritus, urinary retention, sedation, respiratory depression, motor impairment...), or too short satisfactory analgesia (sometimes only at rest but not during mobilization), while others found that the benefit occurred too late during the postoperative period (37-45). Although prolonged postoperative analgesia is not the focus of the present review, there is a trend showing that, in patients undergoing spinal fusion, epidural or intrathecal analgesia is doing less well during the postoperative period in comparison with the same RA technique used for discectomy, laminectomy, or scoliosis correction. This may be explained by the potential presence of pre-existing chronic pain, while patients may have undergone previous hernia surgery or laminectomy.

Finally, there may be some concern to use central nerve blocks in patients with spine pathology, not only due to the need for multiple attempts or risk of failure related to anatomical changes, either pre-existing or induced by previous interventions. Tetzlaff et al. demonstrated that patients with spine problems may experience more than twice the frequency of paresthesias when receiving an intrathecal injection or catheter placement (46).

**Suitable Patients and Surgical Types**

Spine surgery may range from minimal invasive (micro)discectomy to extensive scoliosis fusion. Both an anterior or posterior approach is possible. As a consequence, type of anesthesia will also depend on this. Lumbar interventions may be more suitable for a regional technique, considering that dural punctures should be performed lower than the L2-L3 interspace. Besides a pure regional or general anesthesia technique, combination of both is sometimes to be preferred, especially in procedures of long duration (17, 18).

Despite possible advantages of RA over GA, there are, besides the well known absolute contraindications, some contraindications to RA that are specific for patients undergoing spine surgery. These include severe or multilevel spinal stenosis, near complete-total myelographic block, or myelographic demonstration of arachnoiditis (1).

Previous spine surgery may compromise success of the block, probably more frequently with epidural than spinal anesthesia because of the unreliability of the local anesthetic agent spread. It may also be questioned whether patients having received epidural corticosteroids recently, or a blood patch are the best candidates for epidural anesthesia. However, despite concerns about compromised success rate of epidural techniques, Lavelle et al. demonstrated that epidural analgesia quality in patients with violated epidural spaces is nor different from the control group (47). Bauchat et al. found that epidural labor analgesia was not inferior in patients having undergone previous discectomy (48).

GA will be a better choice for procedures lasting longer than 2 hours or procedures with a possibility of excessive blood loss, such as multiple level laminectomies, extended spinal fusions, and spine distraction procedures using rods or pedicle screws. The upper sensory level should be at Tn or higher, to provide adequate surgical anesthesia, but high levels of motor block are poorly tolerated in the prone position, because of lack of abdominal muscle strength and the inability to breathe deeply against possibly increased abdominal pressure, insofar as intercostal muscles may be paralyzed. A level of surgery higher than Tn is not recommended to be done under neuraxial anesthesia, because of the cardiac and respiratory impact. As a consequence, pure neuraxial anesthesia will be mostly restricted to lumbar (micro)discectomy, laminectomy, or limited multi-level fusion.

Obese patients with protuberant abdomens are also more likely to be candidates for GA, because their ability to breathe in the prone position may be compromised.

To avoid gastric regurgitation, difficult intubation, or placental transfer of medication, pregnant patients may be excellent candidates for a neuraxial technique, but another than the prone position should be considered.

**Intra-Operative Regional Anesthesia Techniques**

Tables 1 to 3 summarize all studies performed during the last 20 years, in chronological order and according to study design.

Spinal anesthesia (Table 1), as the sole intraoperative anesthetic technique, has been successfully used for lumbar disc surgery, single and double level laminectomies, and lumbar spine fusions (1, 4-11). Epidural anesthesia (Table 2), has also been used but to a lesser extent, as evidenced by lower numbers of included patients per study (12-18) than SA. Indeed, epidural anesthesia is more time consuming, may result in less optimal spread of the local anesthetic agent, while many surgeons fear the presence of foreign material such as catheters in the operative field, even at some distance, and eventually
### Table 1
Overview of studies comparing spinal anesthesia with general anesthesia.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>N° of pts</th>
<th>Design</th>
<th>Intra-operative findings</th>
<th>Post-operative findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jellish (1996)</td>
<td>122</td>
<td>RCT</td>
<td>Shorter anesthesia &amp; surgery time</td>
<td>Less pain &amp; PONV Equal urinary retention and length of stay</td>
</tr>
<tr>
<td>McLain (2004)</td>
<td>200</td>
<td>Case control</td>
<td>Shorter anesthesia &amp; surgery time, Lower mean art pressure &amp; heart rate</td>
<td>Less PONV, headache, urinary retention Shorter length of stay</td>
</tr>
<tr>
<td>McLain (2005)</td>
<td>400</td>
<td>Case control</td>
<td>Shorter anesthesia &amp; surgery time</td>
<td>Less pain, PONV, headache, urinary retention</td>
</tr>
<tr>
<td>McLain (2007)</td>
<td>76</td>
<td>Case control</td>
<td>Shorter anesthesia time</td>
<td>Less pain , PONV Longer PACU time</td>
</tr>
<tr>
<td>Sadrolsadat (2009)</td>
<td>100</td>
<td>RCT</td>
<td>Less surgeon satisfaction More blood loss (not significant)</td>
<td>Less hypertension More PONV</td>
</tr>
<tr>
<td>Attari (2011)</td>
<td>72</td>
<td>RCT</td>
<td>Less blood loss More hemodynamic stability Higher surgeon satisfaction</td>
<td>Less pain</td>
</tr>
<tr>
<td>Singeisen (2013)</td>
<td>473</td>
<td>retrospective</td>
<td>Shorter Total anesthesia time</td>
<td></td>
</tr>
<tr>
<td>Kahveci (2014)</td>
<td>80</td>
<td>RCT</td>
<td>Less tachycardia &amp; hypertension Shorter anesthesia time</td>
<td>Less analgesic rescue Lower costs</td>
</tr>
</tbody>
</table>

PONV: postoperative nausea vomiting; RCT: randomized controlled trial; PACU: post anesthesia care unit.

### Table 2
Overview of studies comparing epidural anesthesia with general anesthesia.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>N° of pts</th>
<th>Design</th>
<th>Intra-operative findings</th>
<th>Post-operative findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demirel (2003)</td>
<td>60</td>
<td>RCT</td>
<td>Longer surgery onset time Longer surgery time Equal total anesthesia time Lower blood pressure &amp; heart rate Less blood loss</td>
<td>Less pain &amp; nausea Equal length of stay</td>
</tr>
<tr>
<td>Yoshimoto (2005)</td>
<td>40</td>
<td>prospective</td>
<td>Lower Mean art pressure More hemodynamic stability Less blood loss</td>
<td>Less analgesic rescue</td>
</tr>
<tr>
<td>Papadopoulos (2006)</td>
<td>43</td>
<td>cohort</td>
<td>Equal surgery time</td>
<td>Less PONV Equal pain and length of stay</td>
</tr>
<tr>
<td>Yoshikawa (2011)</td>
<td>75</td>
<td>Retrospective</td>
<td>Longer operating room time Equal procedure time</td>
<td>Equal length of stay</td>
</tr>
<tr>
<td>Ezhevskaya (2013)</td>
<td>85</td>
<td>RCT</td>
<td>GA + EA vs GA</td>
<td>Less blood loss Less stress hormones Lower glucose levels</td>
</tr>
<tr>
<td>Khajavi (2013)</td>
<td>80</td>
<td>RCT</td>
<td>GA + EA vs GA</td>
<td>Less blood loss</td>
</tr>
</tbody>
</table>

PONV: postoperative nausea vomiting; RCT: randomized controlled trial; GA: general anesthesia; EA: epidural anesthesia; LA: local anesthesia.
covered by antibiotics. When epidural anesthesia is performed, it is usually part of a combined neuraxial-general technique. The use of combined spinal-epidural anesthesia (Table 3) is reported in only one study, but has been found to be better than SA with additional perspectives for the postoperative period (49).

Epidural and spinal techniques, combined with general anesthesia, have been reviewed by Tobias et al., but they focused on their use in pediatric surgery only, with special attention for the impact on postoperative analgesia (50).

Studies comparing different regional techniques, positions, or local anesthetic agents are summarized in Table 3.

The surgical procedure can be performed in the lateral, sitting or different prone positions, all for which regional anesthesia have been reported. The sitting position has been found to be extremely comfortable, also offering a cleaner operative field for the surgeon (15). However, it may be more subject to patient’s movement, while hypotension may also be more pronounced with extensive sympathetic blocks. Therefore, epidural anesthesia may be more suitable than a spinal block. Regardless whether the prone or sitting position is used for performing a central nerve block, the patient should, at first, resume the supine position immediately after injection of the local anesthetic agent, to enable block settling. The patient is then placed in the sitting position, or log-rolled to the prone position, and permitted to self-position her/his torso and head.

Yilmaz et al. (51) compared the prone and the knee-chest position in patients receiving spinal anesthesia. They found the latter position to be more pulmonary restrictive than the regular prone position, and, therefore, not to be recommended for patients with pre-existing pulmonary compromise.

Laakso et al. compared a group receiving the spinal injection in the horizontal lateral decubitus position, followed by resuming the supine position for 20 minutes and subsequent positioning in the knee-chest surgical position, with a group given the spinal injection in the knee-chest position with maintenance of that position throughout the procedure (52). The authors found that there was no difference in the obtained block levels, but that the latter technique caused more hemodynamic deterioration, requiring ephedrine though somewhat later than after a block performed in the lateral horizontal position (52).

For the prone position, unless a special frame is used, an alternative position may be mandatory in pregnant patients. A review of 10 cases revealed that 6 patients with spinal disease were operated before 33 weeks of pregnancy with maintenance of the fetus (53). Otherwise, spine surgery is sometimes

Table 3
Overview of studies comparing local anesthetics, regional techniques or positions

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>N° of pts</th>
<th>Design</th>
<th>Comparison</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetzlaff (1995)</td>
<td>53</td>
<td>RCT</td>
<td>Local anesthetics</td>
<td>Plain: longer time to complete block; lower upper sensory level; less hypotension &amp; interventions required; less failed blocks &amp; need for wound infiltration</td>
</tr>
<tr>
<td>Sahin (2014)</td>
<td>60</td>
<td>RCT</td>
<td>Local anesthetics</td>
<td>Levobupivacaine: Higher but later offset of sensory block; Faster offset of motor block</td>
</tr>
<tr>
<td>Düger (2012)</td>
<td>64</td>
<td>RCT</td>
<td>Techniques</td>
<td>Equal hemodynamics</td>
</tr>
<tr>
<td>Laakso (1997)</td>
<td>40</td>
<td>RCT</td>
<td>Position</td>
<td>Knee-chest position: later need for ephedrine; more hypotension</td>
</tr>
<tr>
<td>Nicassio (2010)</td>
<td>261 (23 vs 238)</td>
<td>Prospective cohort</td>
<td>Position</td>
<td>Sitting: more comfort; cleaner surgical field; more dural tears?</td>
</tr>
</tbody>
</table>

RCT: randomized controlled trial; GA: general anesthesia; RA: regional anesthesia.
delayed to be performed at the same time as the C-section or during the subsequent days.

Among all available LA, bupivacaine is still the most commonly used with intrathecal doses as high as 15 mg.

With respect to the choice between plain or hyperbaric solutions, the spread of a plain substance is less affected by patient position than when using hyperbaric LA. As a consequence, plain solutions may produce unreliable or unpredictable levels and quality of anesthesia, as found by Jellish et al. (4). Contrarily, Tetzlaff et al. found that plain bupivacaine is superior to the hyperbaric substance and tetra
caine, producing a denser sensory block and enabling better control of sensory and motor blockade, while having the lowest incidence of an incomplete block (5, 54). According to these authors, hyperbaric bupivacaine had a faster onset for complete motor and sensory block, but these patients had higher upper sensory blocks, greater degrees of hypotension, with more interventions re
quired to treat heart rate and blood pressure changes, and required more often LA wound infiltration (54).

Recently, Sahin et al. found that intrathecal levobupivacaine resulted in faster block recovery, as compared to bupivacaine, which may enable surgeons to faster evaluate postoperative neuro
logical status (55).

**Spine Surgery on an Ambulatory Basis**

Hospital stay has decreased all over for most types of surgery, including spine surgery. Day case surgery for back surgery exists since a few decades. However, only minor surgery such as microdiscectomy may be suitable for ambulatory intervention, while laminectomy only to a lesser extent. This change of practice will not affect the option in favor of regional anesthesia, but may have more impact on the neuraxial treatment of postoperative analgesia, for which systemic medications and wound or root infiltrations or catheters may be an alternative for neuraxial infusions. Good post
operative analgesia remains a priority in spine surgery, as evidenced very recently in 2 studies showing that the still rather high admission and readmission rates were to be related to insufficient analgesia and/or too late scheduling of the surgery in the ambulatory program. Abou-Zeid et al. were able to send 72% of patients home, while the other 28% stayed overnight due to back pain or hypotension (56). Lang et al. (57) reported an admission rate as high as 50.3% with uncontrolled pain (18.9%), late operative start times (14.1%), co
morbidities (13%), and intra-operative complications (11.9%) as main causes.

**Conclusion**

Neuraxial techniques for spine surgery are still receiving much attention in daily practice and literature reports. It may offer several advantages but some concerns have to be taken in consideration. Nevertheless, there are more evidenced based advantages in favor of regional anesthesia, whereas some concerns are mostly theoretical. Optimal planning with the patient and surgeon is of crucial importance. Not all patients and interventions are suitable for a pure regional anesthetic technique. Additional benefit may be expected in the post
operative phase. It remains to be determined whether ambulatory surgery and general anesthesia combined with newer techniques including better systemic analgesia and adjuvant substances, wound or root infiltration, or non-medication techniques (TENS, acupuncture) offer comparable outcome. Additional attention should be paid to long term outcome in terms of chronic pain development and functional rehabilitation.

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