Chapter 6

Special anatomy and classification of fractures

The venous drainage system of the vertebral body and spine and its consequences for balloon kyphoplasty

S. Becker

Because of the possibility of extravasation of cement from the vertebral body, the venous system of the spine should be carefully considered. The vertebral venous system (VVS, Batson's plexus [Batson 1940]) is basically divided into three parts: the external vertebral venous system (EVVS), the basivertebral system (BS) and the internal vertebral venous system (IVVS) [Batson 1940; Clemens 1961; Fleischhauer 1994] (Fig. 16).

The vertebral venous system (Fig. 16)

In principle all vertebral venous systems are built horizontally. Each vertebral body has an outer venous plexus and also has veins running within the vertebral body. Ventrally, the outer plexus lies close to the vertebral body (plexus venosus vertebralis externus anterior), and dorsally it lies on the vertebral arches and ligaments (plexus venosus vertebralis externus posterior). This system is directly connected to the azygos vein and the thoracic hemiazygos vein, as well as to the ascending lumbar veins via the segmental lumbar veins. Thus the inferior and superior vena cavae are directly connected dorsally via this system (Fig. 17).

The basivertebral system

The basivertebral system (BS) lies within the vertebral body, and is formed either by one vein or by a pair of veins which take in smaller veins from the vertebral body. The two veins unite centrally in the basivertebral vein and connect ventrally with the anterior venous vertebral plexus and towards the spinal cord with the IVVS.

![Diagram of vertebral venous system](image)

Fig. 16. The vertebral venous system and its individual parts: The external vertebral venous system (EVVS), the basivertebral system (BS) and the internal vertebral venous system (IVVS)
The internal vertebral venous system

The IVVS (epidural plexus) lies directly in the epidural lipid space. In accordance with the EVVS, the IVVS also forms an anterior venous plexus (plexus venosus vertebralis internus anterior) which is directly connected to the basivertebral vein, and a posterior venous plexus (plexus venosus vertebralis internus posterior) which is directly connected to the external dorsal venous plexus. Thus there are two rings of veins (EVVS and IVVS) surrounding each vertebral body in each segment; the rings are connected via the BS.

All three systems are designed as valveless venous systems. The EVVS and IVVS run along the complete spine, from the hiatus sacralis up to the foramen magnum, and lead anteriorly into the basivertebral venous plexus and posteriorly into the suboccipital sinus [Groen 2004].

The volume of the venous system of the spine is 20 times larger than the arterial volume [Clemens 1961; Vogelsang 1970] and, because of the absence of valves, allows blood flow in both directions, depending on the intra-abdominal and intrathoracic pressures. The function of the inordinately large venous system of the spine is still not clear. Possible functions are: an already laid out collateral circulation in case of occlusion of a vena cava, and the possibility of compensating the venous pressure [Herlihy 1947]; a safety cushion for the medulla [Penning 1981; Reesink 2001]; an absorption space for cerebrospinal fluid [Zenker 1994]; or a cooling mechanism for the central nervous system [Zenker 1996].

The effects that the anatomy has on injection of liquid polymethylmethacrylate (PMMA) cement into the vertebral body are obvious and were shown in vivo in a study by Phillips. Contrast medium is directly instilled during balloon kyphoplasty and vertebroplasty, and it was observed that the medium leaked into the EVVS and the IVVS when using either technique, although significantly less escaped during balloon kyphoplasty than during vertebroplasty [Phillips 2002].

In principle, the cement can escape directly into the greater circulation if either the EVVS or the BS is directly punctured. Furthermore, it is possible that bone marrow enters these veins. The literature describes an increased occurrence of pulmonary embolism after penetration by pedicle screws [Takahashi 2003]. Because of the anatomical situation, the possibility of pulmonary embolism caused by either bone marrow or cement should always be taken into account. The reason for the lower risk of embolism, whether caused by bone marrow or PMMA, during or after balloon kyphoplasty has not been resolved with certainty. The injection of PMMA cement without high pressure plays a decisive role in balloon kyphoplasty [Phillips 2002]; PMMA embolism caused by high-pressure injection of the cement into bone has already been proven to occur in limb surgery [Markel 1999; Orsini 1987]. Furthermore, it is possible that the basivertebral veins are compressed by the balloon and therefore neither fat nor PMMA can pass. A crucial factor regarding the pressure within the whole VVS is the position of the abdomen during the operation.

Compression of the inferior vena cava alone leads to increased blood flow in the VVS via the collateral circulation, and thus to increased risk of embolism [Batson 1940, 1957]. This fact must be taken into account, especially with patients suffering from portal hypertension as a consequence of hepatic cirrhosis. Since cement injection techniques are generally carried out with the patient in an abdominal position, attention should be paid to the intra-abdominal pressure, which must be as low as possible, i.e. the abdomen should be positioned freely during surgery (see Fig. 89, Chapter 11). This means that the venous collateral circulation involving the VVS is reduced to a great extent, and that the blood flows in the caval system. Increased intra-

Fig. 17. Collateral circulation between inferior and the superior vena cava via the venous vertebral system