status, level of mobility and comorbidities.[6] Intra-operative rhabdomyolysis is most frequently documented in the lateral decubitus position.[4,7]

In summary, we have presented a rare case of intra-operative rhabdomyolysis in upper limb surgery. The most effective way to avoid the occurrence of rhabdomyolysis is vigilant prevention with careful pressure-point padding, changing patient-positioning both intra-operatively and postoperatively alongside reducing the operating time.[2] The use of general anaesthetic and regional blocks prevent a patient from repositioning themselves under tissue pressure or contortion. In prolonged procedures in high-risk positions, manipulation of the patient position may be indicated to prevent excessive local tissue compression.

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Rhabdomyolysis and muscle infarcts associated with intra-operative compression

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Editor,

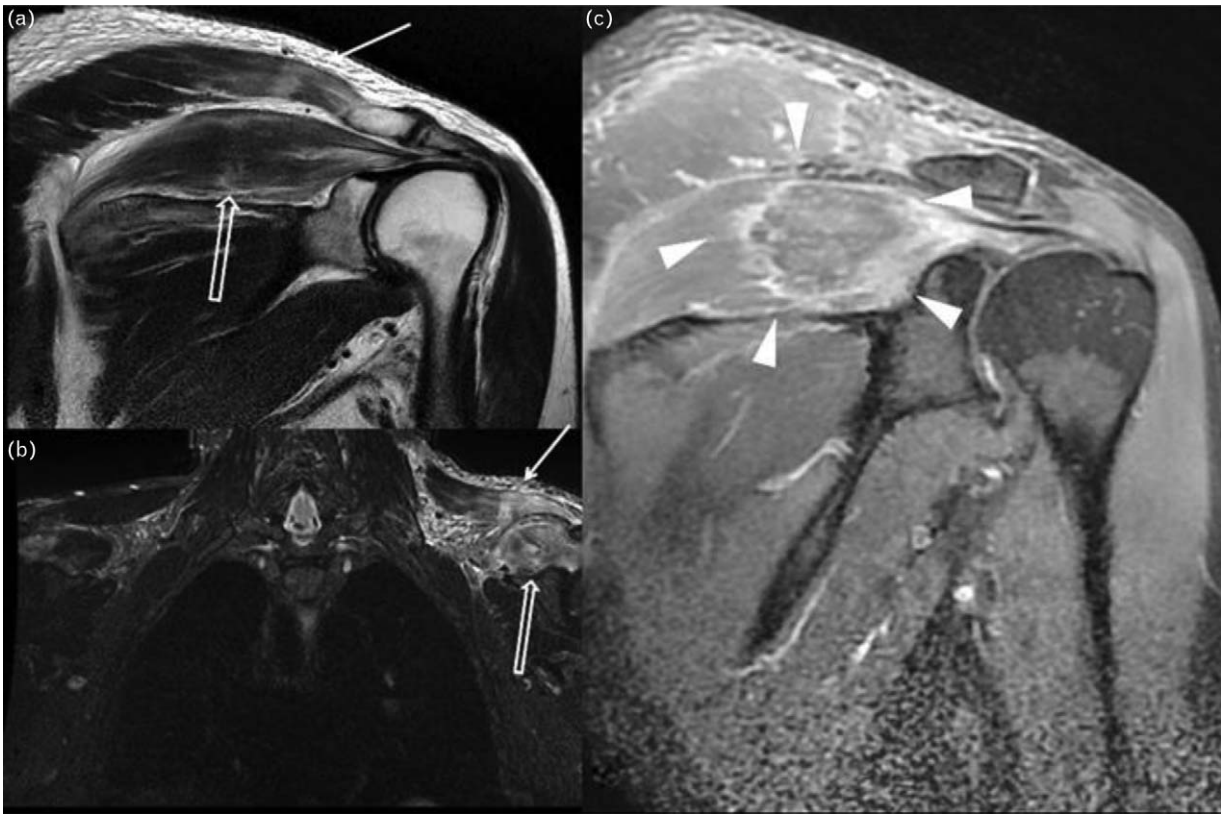
Rhabdomyolysis is a well known complication associated with anaesthesia and surgery, carrying serious consequences for the patient, and associated medicolegal issues.[1] Multiple mechanisms are involved in its pathogenesis.[1] Among these, patient malpositioning is a 'classical' cause. Minimally invasive robotic surgeries, including radical prostatectomy, require long operating times in dedicated positions, increasing the risk of positioning-related complications.

The patients described in this article, consented for publication of these data. Two male patients in their 50s, known to have Gleason 7 prostatic cancer were admitted for robotic-assisted radical prostatectomy with extended pelvic lymph nodes dissection. Their BMIs were 30.6 and 30.8 $kg\,m^{-2}$. General anaesthesia was induced and maintained for about 8 h. The patients were in a supine Trendelenburg position (30°) with gel wedges behind both shoulders and the head. The surgery was successfully performed without any complication. The patients woke up and were transferred to the postanaesthesia care unit. As soon as they regained full consciousness, they reported severe left shoulder pain. Follow-up blood tests showed normal electrolytes but elevated creatinine kinase, myoglobin and lactate dehydrogenase in both patients. An MRI of both left shoulders at day 3 showed 'inflammatory' changes involving the left trapezius muscle, left supraspinatus muscle and tendon as well as the subcutaneous soft tissue around the left deltoid muscle (Fig. 1). The patients recovered with normalisation of serum enzymes levels after couple of weeks and muscles signal on serial MRIs with only minimal muscle atrophy. Their renal function and electrolytes level remained normal throughout their illness.

Intra-operative muscle compression is a well known iatrogenic cause of rhabdomyolysis, which may be complicated by compartment syndrome.[1] Any muscular compartment that undergoes sustained pressure for a long duration can eventually develop rhabdomyolysis.[2] Crush syndrome can be the consequence of any condition of prolonged immobility. A high index of clinical suspicion should lead to adequate diagnostic procedures and rapid management. Multiple serious and life-threatening complications can follow, that need to be promptly treated to avoid disastrous consequences.

MRI is the imaging modality of choice for the workup of muscle diseases. Most MRI sequences can detect changes in muscle shape or volume, whereas an abnormal signal intensity may be detected on specific sequences depending on the cause and duration of muscle disease. Focal or diffuse increase in muscular water content known as 'muscle oedema' seen in rhabdomyolysis and other pathological conditions provokes an increase in T2 signal intensity on MRI that is proportional to the severity of the damage. Return to normal signal intensity is observed with resolution of the lesion. In severe case, muscle infarct or myonecrosis will follow.[3] Multiple case reports describe such events in the literature.[2] Among these, several locations are reported (e.g. gluteal region,

Fig. 1



Coronal T2 (a), short tau inversion recovery (b) and fat suppressed postcontrast coronal T1-weighted (c) MRI images of the left shoulder (patient 2). Abnormal high signal intensity of the left trapezius (thin arrows) and left supraspinatus (open arrows) is seen in the initial MRI images with a nonenhancing area of the distal aspect of the left supraspinatus muscle surrounded by ring enhancement suggestive of muscle infarct (arrowheads).

legs, and upper limbs).[4] To our knowledge, there is no report on rhabdomyolysis of the shoulder muscles in this particular position.

The supraspinatus, scapula and trapezius are not considered a 'classical site' for compartment syndrome, as they are not embedded in a close fascial compartment.[5] However, a compartment syndrome model has been observed in relation to the application of external pressure.[5] In our patients, we hypothesise that compartment syndrome was generated by the pressure of the shoulder pads in the Trendelenburg position, accentuated by the relative high BMI of both patients. Rhabdomyolysis was confirmed by blood tests and MRIs. We assume that the pressure on the left shoulders was greater than that on the right due to a more prominent positioning of the left shoulder pad. Several solutions are proposed in the literature to avoid this specific complication, such as the use of a nonsliding mattress to decrease the pressure on shoulder braces, and to release the Trendelenburg position for few minutes during the surgery to allow reperfusion of the potentially ischaemic or compressed muscles. Furthermore, it has been proved that in comparison with hard support, padding can reduce the pressure on the muscle compartment of the legs by about 16%.[2] In addition, adequate patient selection for specific surgical techniques is of paramount importance (i.e. obese patients, patients with a predictable complex disease). Another way to shorten surgical time in a steep Trendelenburg position is provided by novel surgical tables that are linked to the robotic system, allowing table movement without undocking the robot. All these safety measures might be encouraged to try to decrease the frequency of such incidents.

In conclusion, as observation of our two patients emphasise, minimally invasive robotic surgeries require long operating times in certain positions, increasing the risk of positioning-related complication. A multidisciplinary collaboration between the nursing, anaesthesia and surgical staff for an adequate positioning and monitoring may help to minimise these complications.

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Air embolism during venous sheath replacement

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Editor,

Air embolism is a rare but potentially life-threatening complication related to central venous catheter procedures. Central venous access can allow passage of air directly into the central circulation, where it can obstruct blood flow. The frequency of air embolism in standard central venous line placement is reported as 0.2 to 1%.[1] However, removal and replacement of large bore venous sheaths may pose a greater risk. Such venous sheaths provide large bore central venous access for pulmonary artery catheterisation, pacemaker insertion or massive transfusion. Because of their size, a symptomatic and potentially deadly air embolism may develop rapidly due to greater rate of air passage.

We wished to quantify air embolisms in relation to the removal or replacement of central venous sheaths. Retrospectively, we analysed data from patients who had received central venous sheaths, were aged at least 15 years and were admitted to the ICU, Rigshospitalet, Copenhagen, Denmark, from 1 September 2014 to 31 August 2015. The venous sheaths [3-lumen, 3.0 mm diameter (9 F), length 11 cm, Advanced Vascular Access High-Flow; Edwards Lifesciences] were placed peri-operatively during either emergency aortic aneurism surgery or elective liver transplantation. During the postoperative ICU stay, the sheath was either removed or replaced with a central venous catheter over a guidewire. Accidental sheath removals were excluded. Adverse events triggered interviews with the clinicians involved the patient's care (in September and October 2015) in an attempt to obtain further details. The study was approved by The Danish Data Protection Agency (23–6178) and the Ethical Committee (Videnskabsetisk Komité, Kongens Vænge 2, 3400 Hillerød, Denmark, Chairwoman, Lise Lotte Gluud, Case number H-18061760) on 21 December 2018: they waived informed consent.

Ninety-eight patients undergoing sheath removal or replacement procedures were included. The median age was 65 years [range 16 to 87], 27 (27.6%) were women, 45 (45.9%) had undergone liver transplantation and 21 (21.1%) were receiving positive pressure ventilation during the procedure. Four of the 98 patients (4.1%, 95% CI 0.2 to 8.0) had an event indicative of air embolism, all occurring during replacement (four out of 66 patients, 6.1%, 95% CI 0.3 to 11.8), none during removal procedures. Two of the four events were designated as 'probable', due to symptoms indicative of air embolism occurring during the procedures (Table 1).

The observed incidence of air embolism was much higher than reported in the literature, implying a higher risk when handling large bore central venous lines. This may be explained by air entry during the replacement procedure either along the guidewire when placed through the large sheath, or along the guidewire or newly placed smaller central venous line when these are positioned in the tissue tract left by the large bore venous sheath. Symptoms of air embolism depend on the volume of air and its location within the circulation. Awake patients may complain of dyspnoea, coughing, dizziness, chest pain or 'an impending sense of doom'.[2] Pulmonary and cardiovascular symptoms range from desaturation, tachyarrhythmias, myocardial ischemia, right-sided cardiac failure and right ventricular outlet obstruction with instant circulatory collapse.[3]

Air embolism may be prevented by positioning patients in the Trendelenburg position before central venous catheterisation. In our study, in one confirmed case of air embolism, the procedure was performed with the patient supine. However, to counteract bleeding, the patient was returned to the sitting position before suturing and dressing the site. The second confirmed case involved a patient in the Trendelenburg position who hyperventilated during the procedure. Thus, despite using optimal positioning, air embolism may still occur.[4] Three of the cases involved spontaneous breathing