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ORIGINAL ARTICLE - SPINE

L5 corpectomy—the lumbosacral segmental geometry and clinical outcome—a consecutive series of 14 patients and review of the literature

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Abstract
Purpose We analyzed the lumbosacral segmental geometry and clinical outcome in patients undergoing L5 corpectomy.
Methods Fourteen consecutive patients who underwent L5 (n = 12) or L4 + 5 (n = 2) corpectomy at our department between January 2010 and April 2015 were included. All patients underwent a baseline physical and neurologic examination on admission. The diagnostic routine included MRI and CT scans and, if possible, an upright X-ray of the lumbar spine before and after surgery. The local lordosis angle [L4(L3)-S1] was measured.
Results The most common pathology was infection (N = 7), followed by neoplastic disease (n = 3), pseudarthrosis (n = 2) after previous spinal fusion procedures and burst fractures (n = 2) of the L5 vertebral body. We observed seven complications (2 intraoperative; 5 postoperative) in five (36%) patients. Three patients needed revision surgery because of cage subsidence and/or dislodgement (21%). Additional anterior plating was used in two of the revision surgeries to secure the cage. Two spondylodiscitis patients (14%) with complications died of sepsis. Of the 12 remaining patients, 8 were available for follow-up.
Conclusion L5 corpectomy is a technically challenging but feasible procedure even though the overall complication rate can be as high as 36%. The radiologic and clinical outcome seems to be better in patients with a small lordosis angle between L4(L3) and S1, since an angle of >50 degrees seems to facilitate cage dislodgement. Anterior plating should be considered in these cases to prevent implant failure.

Keywords Anterior lumbar fusion · L5 corpectomy · Lumbosacral junction · Sagittal balance

Introduction

Some pathologies such as tumorous (primary or metastatic) spine disease, spondylodiscitis or comminuted vertebral body fractures mandate anterior column reconstruction as a single- or two-staged procedure. The specific anatomy of the lumbosacral region makes the L5 corpectomy and vertebral column reconstruction a technically highly demanding and challenging procedure and is associated with a high complication rate. The available literature on this topic is scarce and consists of 3 retrospective series with only 25, 19 and 15 patients, respectively, and a few case reports [1–8].

Material and methods

Patient population

Fourteen consecutive patients (9 male, 5 female) who underwent L5 corpectomy at our institution were included between January 2010 and April 2015. Twelve patients were

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treated with a L5 corpectomy; in two cases a L4 + L5 corpectomy was performed. Patient's mean age was 64 ± 15.1 years (range 24–84 years). The most common pathology was infection (N = 7). Three patients had neoplastic disease, two a pseudarthrosis after previous fusion procedures and two patients presented with complete burst fractures of the fifth lumbar vertebral body. Three patients (21%) had had previous anterior retroperitoneal surgery at the index level. All patients underwent a baseline physical and neurologic examination on admission. The diagnostic routine included MRI, CT scan and, when possible, long-standing holospinal X-rays before surgery. All patients underwent a two-staged procedure with posterior lumbosacral pedicle screw fixation followed by corpectomy via an anterior retroperitoneal approach (Figs. 1, 2).

Posterior pedicle screw fixation

The instrumentation was inserted either through an open midline (N = 13) or via a minimally invasive percutaneous approach (N = 1). Depending on the pathology and/or bone mineral density, either a short-segment fixation from L4 to S1 (N = 3) or a longer construct fixation (N = 11) extending from L4 to S2 with trans-sacroiliac screws or the ilium with iliac wing screws was performed. Seven posterior pedicle screw instrumentations were performed with 3D-fluoroscopic navigation and seven with the freehand technique depending on the availability of a navigation system. In two patients with osteoporotic fractures, posterior instrumentation was performed with polymethylmetacrylate (PMMA)-augmented pedicle screws. All screws were instilled with 2-3 ml PMMA under serial lateral fluoroscopic control. There were no clinically or radiologically relevant PMMA leakages.

Posterior decompression with laminectomy was performed in cases with spinal canal compromise and a spinal canal narrowing of more than 30% by a retropulsed posterior vertebral wall fragment, posterior wall bulging or tumor mass.

Posterolateral fusion with morselized autologous bone was performed in all but the one minimally invasive procedure. A subfascial suction drainage was routinely placed and removed after 72 h in infection cases and after 24 h in all other procedures.

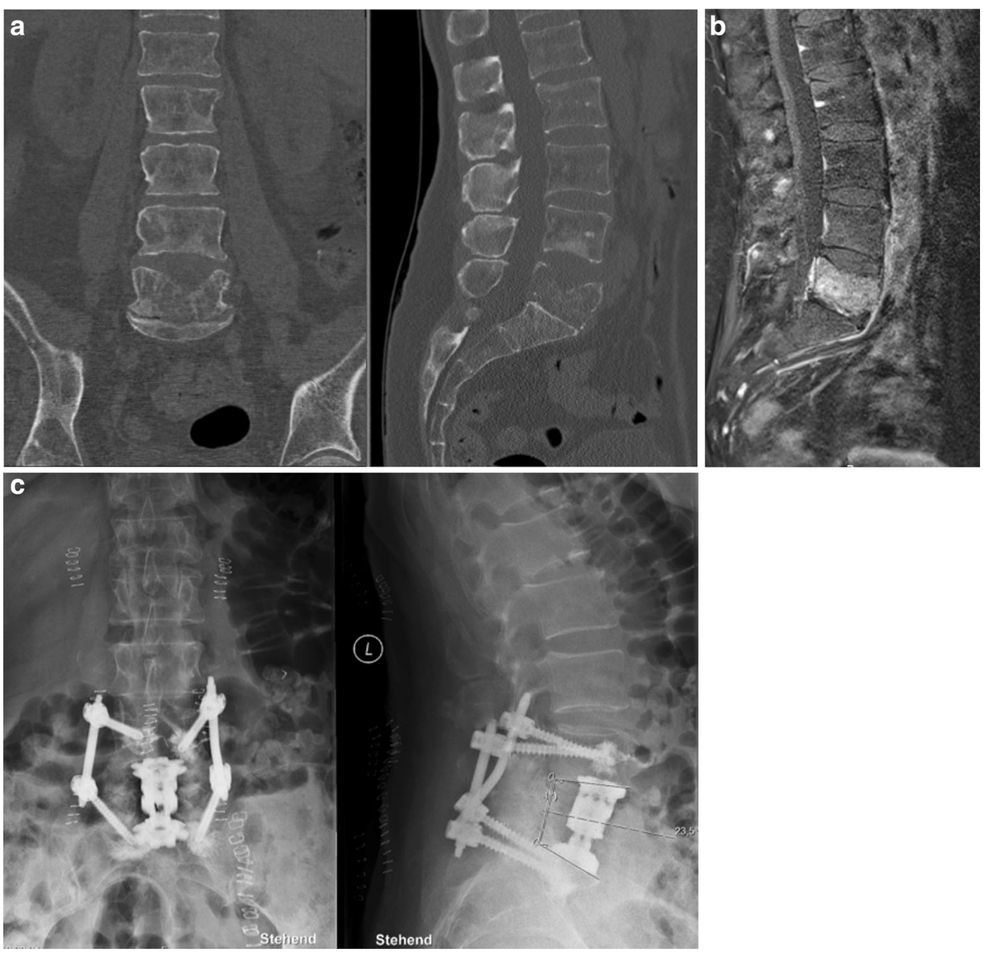

Fig. 1 **a** Preoperative computed tomography (CT) demonstrating a pathologic fracture of L5 in a 64-year-old female patient with a history of breast cancer. **b** Preoperative magnetic resonance imaging (MRI) indicating a tumorous infiltration of the L5 vertebral body. **c** Standing lumbar spine X-ray after ambulation with intact material. Note the local lordosis angle of 23.5° and the minor PMMA leak anterior to L4

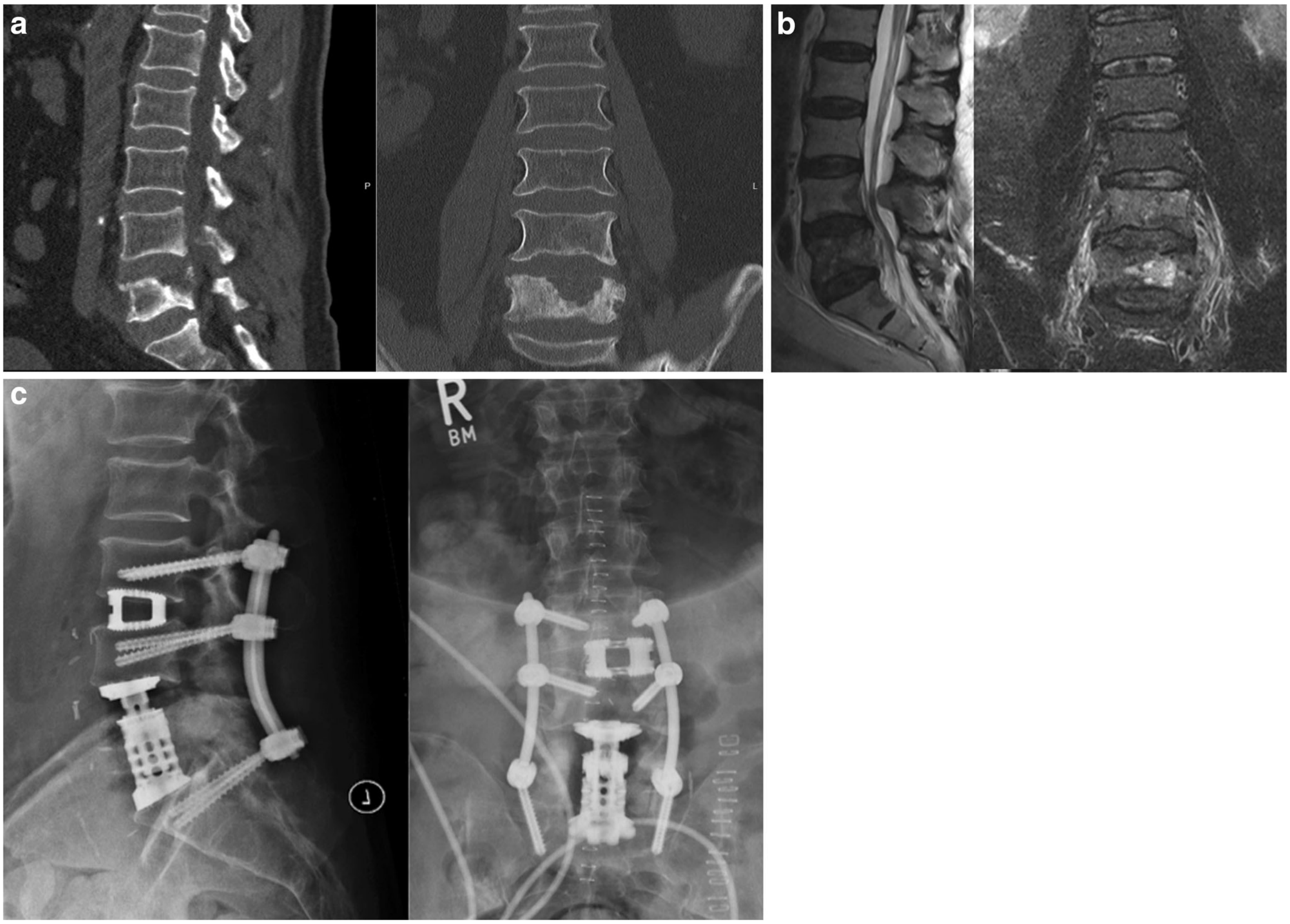

Fig. 2 **a** Preoperative CT demonstrating a pathologic fracture of L5 in a 69-year-old male patient with a history of prostate cancer. **b** Preoperative MRI indicating a tumorous infiltration of L5 and L4. Note the posterior tumor mass narrowing the spinal canal at L4. **c** Standing lumbar spine X-ray after ambulation with intact material. The instrumentation was extended to L3 because of the need for decompressive laminectomy at L4. An anterior lumbar interbody cage was added to support the L3/4 segment

Anterior surgery

All but three patients were operated on through a left-sided retroperitoneal approach. A midline or left paramedian incision was made. After opening the rectus abdominis muscle sheath, blunt finger dissection in the plane between the abdominal muscular wall and the peritoneal sac was used to expose the retroperitoneal fat and the ipsilateral psoas muscle.

After mobilizing the peritoneal sac and the ipsilateral ureter, the left common iliac vessels were identified. Exposure of the surgical site was maintained by radiolucent retractor blades. First, the left common iliac artery and vein were held latero-cranially to mobilize the prevertebral fat including the superior hypogastric plexus and ligate the median sacral vessels and finally to perform a discectomy on L5/S1.

Second, the L4/5 segment was addressed with preparation of the ipsilateral common iliac artery and identification of the iliolumbar/ascending lumbar veins and L5 segment vessels. The segment and ascending lumbar vessels were ligated and cut to allow for a complete mobilization of the left common iliac vein contralaterally. After L4/5 discectomy and lateral resection, borders were identified and the L5 vertebral body reduced and removed. Then, the posterior longitudinal ligament was removed. After hemostasis, the anterior vertebral column reconstruction was performed with insertion of a lordotic expandable cage. The needed endplate angulation was measured on preoperative imaging and confirmed with intraoperative fluoroscopy. After securing the distraction of the cage, the wound was irrigated with 1–3 l warm saline and closed in the usual fashion. Routinely an expandable titanium cage (Obelisc, Ulrich GmbH & Co.KG, Ulm, Germany) vertebral body replacement was used.

In patients who had had previous surgery for colon resection or inguinal hernia repair, the dissection plane was not easily found because of scar tissue and adhesions. Two retroperitoneal approaches were converted to transperitoneal access from the left side. One patient with a history of multiple previous abdominal operations for peritonitis was operated on from a right-sided transperitoneal approach performed by an abdominal surgeon. The anterior surgeries (including all but one anterior approach) were performed by B.M., M.V. and F.R.

Radiologic assessment

All radiologic measurements were performed independently by a neurosurgeon (M.V.) and a neuroradiologist (F.Z.) using our institutional PACS system, and the mean value of both measurements was used for further assessment. We measured the local lordotic angle of the endplates (sagittal Cobb angle) and the overall lumbar lordosis. The postoperative lumbar lordosis was measured where possible on upright lateral X-rays; only two patients who could not be mobilized received CT scans in the supine position.

Statistical analysis

Statistical analysis was performed using SPSS 21.0 for Mac (SPSS Japan Inc., Tokyo, Japan) and Microsoft Excel 11 for Mac 14.4.8 (Microsoft Corporation, Redmont, WA, USA). Student's t-test was used for the comparison of continuous variables, and statistically significant differences were accepted at $p < 0.05$.

Results

Perioperative findings

Average time for the anterior surgery with L5 replacement was 186.9 ± 53.9 min (range 107–268 min). The mean preoperative hemoglobin (Hb) was 9.56 ± 1.28 mg/dl (range 7.5–12.3 mg/dl). Seven patients (50%) needed intraoperative red blood cell (RBC) transfusions. The substituted patients received on average 2.1 ± 1.1 units of packed RBCs (range 1–4). The mean postoperative Hb was 9.04 ± 0.97 mg/dl (range 7.2–10.3 mg/dl).

Complications

We observed a total of seven peri- and intraoperative complications in five patients.

There were no intraoperative complications during the posterior pedicle screw fixations. Two (14%) intraoperative complications occurred during the anterior procedures. One was a minor iliac vein injury that was repaired with fibrin glue without further postoperative sequelae. The other was severe intraoperative arterial hypotension due to septic shock, and the surgery had to be aborted in a spondylodiscitis patient.

The average postoperative hospital stay was 18.6 ± 20.6 days (range 4–74 days). All patients except for three were able to ambulate when discharged from the hospital.

Postoperatively, two patients died following septic multiple organ failure.

We observed three anterior cage dislocations in three patients (21%) within 3 weeks after surgery. The first happened immediately after patient mobilization in the first week. The second occurred because of an L4 endplate fracture following a new trauma in the second week after surgery. The last cage dislodged in an immobilized septic patient because of a pathologic sacral fracture with destruction of >50% of the S1 endplate 3 weeks after anterior L5 reconstruction.

All three dislodged cages were revised. In two cases, we used additional anterior plating to stabilize the reinserted cage (Fig. 3). In the last case, anterior plating was not possible because of an S1 fracture. During one of the cage revision surgeries, the small intestine was injured because of distinct peritoneal adhesions after a previous laparotomy. Adhesiolysis and resection of the injured small intestine

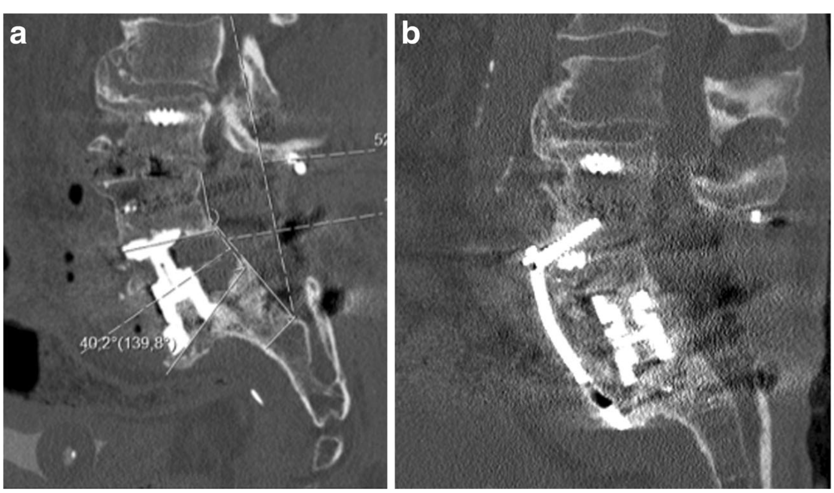

Fig. 3 **a** CT after ambulation disclosing a new S1 fracture and cage dislodgement in a 72-year-old male patient with a history of an erosive spondylodiscitis following previous fusion attempts. **b** CT after revision and securing the cage with an anterior plate

followed by a side-to-side anastomosis were performed by an abdominal surgeon after the dislodged cage had been removed, and an autologous fibular graft was inserted and secured with screws. The intestinal lesion healed, and oral nutrition uptake was resumed.

Of the 12 surviving patients, 8 were available for follow-up. The mean follow-up time was 5 ± 3.3 months (range 2–11). Seven patients were still ambulatory on the last follow-up and reported better mobility compared to preoperatively (Fig. 3).

Radiologic findings

The mean local lordotic angle [endplate L4 (L3) to endplate S1] after posterior fixation before L5 corpectomy was 31.2 ± 8.9 degrees (range 17.5–48.9 degrees) after anterior surgery 35.6 ± 10.7 degrees (range 21.1–55.4 degrees). Patients with non-dislodged cages had a mean postoperative local lordotic angle of 32.1 ± 8.4 degrees (range 21.1–46.2 degrees). The patients with cage dislocations had higher mean local lordotic angles of 47.3 ± 10.3 degrees (range 21.1–55.4 degrees), but there were no significant differences between the two groups ($p = 0.106$). In a subgroup analysis, the patients with spontaneous cage dislocations and those without cage dislodgement were compared. Patients with non-dislodged cages had a significantly lower mean local lordotic angle than the patients with spontaneous cage displacements (32.1 ± 8.4 degrees vs. 53.1 ± 3.3 degrees; $p = 0.0026$).

Discussion

Access complications

L5 corpectomy is a rather uncommon procedure. One of the major challenges is the vascular anatomy of the lumbosacral region with the left common iliac vein crossing the spine diagonally anterior to the L5 vertebra. Therefore, intraoperative vascular injuries are the most frequently encountered lesions during anterior spine procedures.

The reported total complication rate for vascular injuries in anterior spine surgery varies from 7.9% to 13.8% [9–12]. The highest complication rates were observed in tumorous spine disease (36%) and redo cases (52%) [12].

The largest retrospective L5 corpectomy series with 25 procedures reports a 4% rate of vascular complications [8]. In our series, we experienced one (7%) injury of the iliac vein, which could be fixed immediately without further sequelae. Some authors seem to perform an additional L4 corpectomy even if the lesion might be limited only to the L5 vertebra to allow for better manipulation and easier access to the vertebral bodies for corpectomy and cage insertion [13]. This was not necessary in any of our cases. We observed one small intestine lesion in a redo case following a cage displacement. No gastrointestinal complication was reported in any of the three previous L5 corpectomy series [2, 6, 8]. A case of delayed small bowel obstruction after a Charite total disc replacement (TDR) revision has been described [14]. Balsano et al. described a rare case of bowel perforation in a retroperitoneal lateral approach [15]. We had no cases of urologic complications, abdominal hernia or postoperative hematoma. No patients reported retrograde ejaculation (RE), whereas some authors report postoperative RE rates as high as 9.8% for TDR and 7.4% for ALIF [16].

Lumbosacral geometry

The bony anatomy of the junctional L5/S1 zone constitutes the next major challenge. Anterior vertebral column surgery in patients with extreme lumbosacral lordosis is not only technically challenging during surgery, but also a challenge postoperatively because of the high rate of cage dislocations. The reason for this seems to be not only the extreme lordosis angle per se, but also a high S1 slope and slippage while the patient is in an upright position. To prevent later cage dislocations, it is crucial to choose an optimally sized cage with respect to cage height, endplate dimensions and, what is probably the most important factor, the proper endplate angulation. We measured the preoperative local lordotic angles between the endplates of adjacent vertebrae in all patients. In the majority of cases, cages with 32 mm × 26 mm oval endplates with the appropriate lordotic angle could be inserted. To prevent mechanical failure, Shousha et al. also advocate large footprint titanium cages [8]. Lee et al. reported the need for lordotic cages to prevent an angulation mismatch between the cage and the vertebral endplates. All their implanted straight non-lordotic cages failed, whereas their lordotic cages showed no dislodgements on follow-up after more than 2 years [6]. These data are consistent with our findings. In our series, we experienced three mechanical cage failures. One patient was diagnosed with a new osteoporotic fracture of the L4 endplate. The cage subsided into the L4 vertebral body and migrated anteriorly. The two other implant failures occurred in spondylodiscitis patients with a local lordosis angle of over 50 degrees. In these two cases, we observed a >10° mismatch between the bony endplate anatomy and the cage endplate geometry since the implants only allowed for a maximum 40° lordosis. Therefore, additional anterior plating was used in two revision surgeries to secure the cage. The mean lordotic angle in the non-failed group was markedly lower with 32.1 degrees (range 21.1–46.2°) ($p = 0.0026$).

Biomechanical aspects

Our findings seem in concordance with published studies on biomechanical spine testing. In vitro testings in anteriorly reconstructed lumbosacral junctions after removal of the caudalmost disc and facets in a porcine model showed an increased rigidity of the construct on axial loading by adding an anterior cage to the pedicle fixation. Only after addition of both iliac screws and an interbody cage did the range of motion of the spine decrease significantly, and failure occurred proximal to the construct on destructive testing [17]. There was no significant range of motion difference between a short (L4-S1) and long (L3–4-S1-ilium) posterior fixation in a cadaveric L5 corpectomy model. Adding anterior plating (L4-S1) to the instrumentation increased the construct rigidity significantly [18].

Conclusion

L5 corpectomy and reconstruction of the lumbosacral junction is a complex but viable procedure. Patients with extreme lordosis angles in the lumbosacral junction seem prone to cage dislocation. However, it is associated with a rather high rate of complications. A high lordotic angle ≥50° and/or pathologically reduced bone mineral density as in osteoporosis seem to be major risk factors for implant failure after L5 corpectomy. We therefore recommend additive anterior plating to secure the cage in these cases in addition to the optimal sizing of the cage. This technically highly demanding procedure should be confined to spine centers with extensive expertise in complex spine surgery and 360° vertebral column reconstruction.

Compliance with ethical standards

Funding No funding was received for this research.

Conflict of interest B.M.: Consulting: DepuySynthes, Brainlab, Medtronic, Ulrich, Spineart, Reliviant. Received funding from: DepuySynthes, Brainlab, Medtronic, Ulrich, Reliviant. Royalties/Patent: Ulrich, Spineart.

J.G.: Consulting: BrainLab.

All other authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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