MDCT in abdominal wall pathology and its intestinal complications

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Learning objectives

The main objective is to show the effectiveness of last-generation MDCT in the diagnosis and assessment of the abdominal wall pathology, focused mainly on primary and incisional hernias.

We will illustrate the different types of primary and incisional hernias, their classification by the European Hernia Society and their possible complications.

Finally we will show which information may be relevant to the surgeon in planning the surgical treatment, and how we can identify the early postoperative complications that can result from the surgical repair of these defects.
Background

Abdominal wall hernias are a common finding in the different abdominal imaging techniques. They often appear in asymptomatic patients or in cases unsuspected by the clinician or patient, but they are one of the most common indications for major surgery. The diagnosis of this pathology is based on clinical examination and the information obtained by this is usually sufficient for treatment planning. However, there are situations such as obesity, groin pain of unknown cause, patients with a history of previous abdominal surgery or hernias of atypical location where the physical examination does not provide the necessary information and clinical diagnosis can be difficult. In all these cases, MDCT plays a fundamental role.

MDCT, by its exquisite anatomic detail, its multiplanar capabilities and availability, is currently the most used imaging test in the overall assessment of the abdominal wall pathology. Moreover, with current multidetector equipments is an extraordinarily rapid test where the acquisition is done in few seconds. It is an effective technique in detecting primary and incisional hernias; it allows classification with low interobserver variability and positive predictive value close to 95 % Fig. 1 on page 4. It also allows evaluating the hernial content, differentiating hernias from other situations that can simulate hernias like abdominal masses or asymmetries, and detect complications related to the hernia or early complications secondary to the surgical treatment.

These MDCT findings help to optimize treatment planning and improve the communication to clinicians.
Fig. 1: MDCT, with its multiplanar capabilities and the possibility of oblique reconstructions, allows identifying accurately very little abdominal wall defects (arrows). It is useful to evaluate the size of the orifice and the hernial content (in this case, there was an orifice less than 1 cm with fatty tissue inside the hernia sac).

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Findings and procedure details

Anatomy of the abdominal wall

The abdominal wall is the boundary of the abdominal cavity. Its anterior limit is formed by the rectus abdominis muscle, and laterally by three muscle planes (obliquus externus, obliquus internus and transversus abdominis muscles). Dorsally there are different muscle groups (paraspinal muscles, quadratus lumborum, serratus inferior, latissimus dorsi, etc.). These muscles converge in different aponeurotic sheaths, like the linea alba between the rectus abdominis muscles or the semilunar line between the rectus muscles and the lateral group Fig. 2 on page 11. If there has not been a history of prior surgery, most of the hernias originate in these fascial sheaths. In the rear region there are also weak areas. One of these is the triangle of Petit, delineated between the muscle insertions of the lateral group, the iliac bone and quadratus lumborum.

MDCT allows an overall assessment of the abdominal musculature: parameters such as the thickness, the length or the presence of fat substitution produced by denervations or myopathies can be accurately assessed. The integrity of the fascial sheaths, identifying tears or holes, and the tendinous insertions can also be detailed Fig. 3 on page 11.

DIAGNOSIS AND CLASSIFICATION OF PRIMARY AND INCISIONAL HERNIAS

MDCT allows obtaining the following information:

*Diagnosis of hernia:* The diagnosis of hernia is established when there is a dehiscence or rupture of the abdominal wall with intra-abdominal contents (fat, bowel loops) outside their natural boundaries. This may differentiate a true hernia from a diastasis, in which there is no hole or defect in the abdominal wall Fig. 4 on page 12.

*Location:* Although there are multiple classifications, the European Hernia Society has recently established a classification of primary and incisional hernias based on the location and size of the defects Fig. 5 on page 13. Primary hernias are classified into midline (epigastric and umbilical) and lateral hernias (lumbar and Spieghelian). The location of incisional hernias is more diverse and also its classification. Midline hernias are divided into 5 areas from the xiphoid to the pubis and lateral into 4 Fig. 6 on page 14.
In the inguinal region, hernias are classified as direct, indirect and femoral, depending on the relationship of the hernia neck to the inferior epigastric vessels and the common femoral vein. Direct inguinal hernia originates medial and anterior to the inferior epigastric vessels and extends inferiorly displacing laterally the inguinal canal and its components Fig. 7 on page 15. Indirect inguinal hernia, conversely, extends through the inguinal canal into the scrotum in men or the labia majora in women and originates laterally to the inferior epigastric vessels Fig. 8 on page 16. The femoral hernia is more lateral than previous, originating inferiorly to the epigastric vessels and is in contact with the medial aspect of the common femoral vein Fig. 9 on page 16.

Orifice measurement: Primary hernias usually have a defect with a circular or slightly ovoid morphology, so it is valid to measure its transverse diameter in order to classify them. They can be ranked into three groups based on the size of this transverse diameter: small (less than 2 cm), medium (2 to 4 cm) and large (greater than 4 cm). On the other hand, the orifices of incisional hernias are usually irregular, so the maximum longitudinal and transverse diameters must be measured. To accurate these measurements, although transversal and sagittal images can be used, is recommended to obtain oblique multiplanar reconstructions oriented parallel to the long axis of the muscle defect Fig. 10 on page 17. The European Hernia Society has classified incisional hernias depending on their maximum transverse diameter: less than 4 cm, 4-10 cm and greater than 10 cm Fig. 5 on page 13.

Number of orifices: Incisional hernias usually show several orifices. In these cases the location and size of each hole must be specified, but also the maximum transverse and longitudinal diameter gathering all holes like a single defect Fig. 11 on page 18.

Dynamic studies: To study hernias in which the content enters and leaves the herniary sac spontaneously, dynamic exams with Valsalva’s maneuver are recommended. In the supine position intraabdominal pressure decreases causing a spontaneous reduction of the herniated contents and even a decrease in orifice diameters. Valsalva’s maneuver (such as coughing and defecation) reproduces truthfully the abdominal pressure of activities of daily living. This simple maneuver not only allows a better assessment of the herniated content Fig. 12 on page 19, Fig. 13 on page 20, but also minimizes false negatives. It is noteworthy that up to 10% of hernias are not detected in studies without Valsalva’s maneuver. Lateral decubitus position also facilitates the observation of this type of hernias of the abdominal wall, and is also an excellent method in doubtful cases.

COMPLICATIONS
MDCT has high efficacy in the diagnosis of the complications that the hernia may present. The most frequent complications of hernias are: incarceration, strangulation and bowel obstruction Fig. 14 on page 21, Fig. 15 on page 22. These complications can appear isolated or associated, and usually present as emergent pathology. In most cases an imaging test such as a CT will be required to establish a rapid and accurate diagnosis, since surgical treatment will often be mandatory. A CT with intravenous contrast will allow to identify properly the anatomical structures involved and to assess signs of ischemia in the intestine walls herniated and the situation of the mesenteric vessels.

Postoperative complications

Although complications after surgical repair can occur frequently, most of them are minor and less than half of these cases will require further surgery. The most common complications include hernia recurrence, hematoma, seroma, enterocutaneous fistulae, intestinal occlusion and infection of the surgical wound or the prosthetic material employed in the reparation of the defect Fig. 16 on page 23, Fig. 17 on page 23. Abscesses in the surgical area after a hernia reparation are common (20% approximately), especially in large hernias. In these cases a major dissection of the subcutaneous tissue is performed, and only by physical examination fluid collections cannot be easily distinguished from a recurrent hernia. MDCT will allow early detection of these postoperative complications, being the technique of choice when there is a clinical suspicion.

PREOPERATIVE PLANNING

The complexity of the surgical methods employed in the hernia reparation, the widespread of laparoscopic surgery and the use of new prosthetic materials has created a growing demand of information for planning the most appropriate surgical approach. Nowadays MDCT can provide relevant information which may facilitate or even modify the therapeutic option.

Assessment of the abdominal muscles.

When repairing a hernia, it is important to know the condition of the muscles of the abdominal wall (rectus abdominis, obliques and transversus abdominis). It is not uncommon to find areas of muscle atrophy caused by previous surgical denervation or complete or partial tears, not only at the site of the hernia, but also in adjacent areas where the prosthesis was going to be fixed Fig. 18 on page 24. Knowing this situation
may also change the surgical approach, helping to choose the appropriate size and composition of the prosthesis in each situation.

**Volume quantification in large hernias.**

One of the emerging applications of MDCT is large hernias or hernias presenting "loss of domain". When the defect is greater than 10 cm and the estimated hernia volume is greater than 10 liters, the surgical reparation will sometimes require creating a therapeutic pneumoperitoneum. The effect of gas pressure maintained on the abdominal wall causes stretching of the muscle fibers with a consequent increase in fascicular length, and, therefore, this becomes in a greater volume of the recipient abdominal cavity. The increase that can be achieved with this technique of the pneumoperitoneum can be quantified by CT. Some studies have shown that the abdominal wall can increase its length approximately in 8 cm, thus increasing the capacity as a continent of the abdominal cavity and favoring a tension-free repair Fig. 19 on page 25. In special cases such as obese patients, physical examination does not provide enough information about the herniated volume. In these cases, MDCT allows to calculate this volume (content), the volume of the abdominal cavity and the volume of gas that is needed to insufflate in order to increase the abdominal capacity and get the reintroduction of the herniated volume without an abrupt increase of the intraabdominal pressure.

Another techniques such as the employment of botulinum toxin is being used in order to achieves a temporal relaxation of the muscle fibers, getting an easier reparation and avoiding problems related to the compartimental syndrome that may happen after a rapid increase of the intraabdominal pressure.

Some methods based on the information obtained by MDCT have been published showing different ways to calculate the volume of the hernia and the abdominal cavity. The volumetric data obtained can be processed using semi-automated software Fig. 20 on page 26 or simple formulas based on three-dimensional diameters. Applying the ellipsoid volume formula, that consider this geometric figure similar to the morphology of the hernia sac or even the abdominal cavity, an accurate approach can be done Fig. 21 on page 27.

**Angiographic assessment of the vascularization of the abdominal wall.**

Knowing the vascular anatomy of the muscles and the subcutaneous tissue of the abdominal wall may be of interest in the surgical planification. Muscle vasculature depends mainly from upper and inferior epigastric vessels, while the
subcutaneous tissue depends from perforator branches that come from deep epigastric vessels Fig. 22 on page 28, Fig. 23 on page 29. Vascular CT studies can identify these perforator vessels in the subcutaneous tissue in order to avoid injury during surgery or respect them for vascularized skin flaps Fig. 24 on page 29. Although subcutaneous vasculature is formed by small vessels and blood supply is not decisive, it is important to try to respect these vessels in order to avoid necrosis of the skin edge of the surgical wound. In large hernias and those with "loss of domain" a large dissection of the subcutaneous tissue is performed so skin necrosis is a frequent and feared complication requiring debridement and multiplying the risk of prosthesis infection.

**Evaluation of concomitant pathology.**

There are several conditions that facilitate the appearance of abdominal wall hernias, situations in which hernias can be found with a higher prevalence. Among them, chronic obstructive pulmonary disease and emphysema, as well as abdominal aortic aneurysm are the most frequent. For this reason, a respiratory evaluation must be made in these patients, normally with functional respiratory tests. The abdominal wall study allows evaluating abdominal aorta and possible digestive tract complications as intestinal obstruction or ischemic. We must also remember that there are conditions such as hiatal hernias and small abdominal wall weaknesses that can worsen after the hernia repair, mainly due to the increase of the intraabdominal pressure. In addition, CT may reveal other pathologies not previously suspected, that caused or contributed to the hernia, such as large intraabdominal cystic tumors Fig. 25 on page 30.

**MDCT image acquisition protocol**

Most last-generation MDCT use an acquisition thickness less than 1 mm, although between 3 and 5 mm is sufficient to reconstruct transversal and sagittal images. The great data volume obtained allows multiplanar reconstructions (sagittal, coronal, and oblique) and high quality diagnostic images. This volume of data has also the ability to generate three-dimensional multiplanar views that provide more information and improve the visual information transfer to the surgical specialist. Importantly, despite the dramatic increase in information obtained by MDCT, the dose radiation is not increased. The new equipments have efficient tools in the control of the radiation dose (iterative reconstruction, exposure filters, and better detectors) that not only do not increase but decrease the dose compared to the old CT scanners.
In MDCT studies of the abdominal wall, the use of intravenous contrast media is not always necessary, although its use is unavoidable when the exam is performed to discard the potential complications and to study the vascularization of the abdominal wall. Positive oral contrast (barium or iodine) may help in identifying the herniated small bowel loops Fig. 26 on page 31 and differentiate seroma from other circumstance. Its use is not required and is usually sufficient with an overload of water before the scan to distend adequately the bowel loops.

All the specifications of the protocol that we use in our new 256-MDCT are resumed here.

<table>
<thead>
<tr>
<th>Study area</th>
<th>From diaphragm to pubic symphysis</th>
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<tbody>
<tr>
<td>Functional exam</td>
<td>Valsalva’s maneuver</td>
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<tr>
<td>Acquisition time</td>
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<tr>
<td>Radiological technique</td>
<td>120 kV</td>
</tr>
<tr>
<td></td>
<td>≈160 mAs with automatic modulation</td>
</tr>
<tr>
<td></td>
<td>Collimation 0,6 mm x 128 detectors</td>
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<tr>
<td>Image reconstruction</td>
<td>Data volumen 0,8 mm</td>
</tr>
<tr>
<td></td>
<td>Transversal series: 3 mm</td>
</tr>
<tr>
<td></td>
<td>Sagittal series: 3 mm</td>
</tr>
<tr>
<td>IV contrast</td>
<td>Only if complication is suspected</td>
</tr>
<tr>
<td>Oral contrast</td>
<td>Gastrografin® or barium sulphate</td>
</tr>
<tr>
<td>Radiation dose</td>
<td>4-8 mSv</td>
</tr>
</tbody>
</table>

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Fig. 3: Detachment of the iliac insertion of the obliquus internus and transversus abdominis muscles (arrows). Shortening and thickening of both muscles can be appreciated. Detachment causes weakness of the abdominal wall at this level. This defect cannot be denominated hernia because of the integrity of the obliquus externus abdominis.

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Fig. 4: A and B) MDCT three-dimensional reconstructions in a patient with a clinical suspicion of middle-line incisional hernia. C and D) Transversal and coronal images show diastasis of the rectus and little orifices in the epigastric area without intestinal herniations.

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### European Hernia Society (EHS) classification for primary and incisional abdominal wall hernias.

<table>
<thead>
<tr>
<th>EHS classification</th>
<th>Primary abdominal wall hernia</th>
<th>Incisional hernia</th>
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<tbody>
<tr>
<td><strong>Anatomic localization</strong></td>
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<td>- Middle line</td>
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<td>M1 Subxiphoid</td>
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<tr>
<td></td>
<td></td>
<td>M2 Epigastric</td>
</tr>
<tr>
<td></td>
<td>Umbilical</td>
<td>M3 Umbilical</td>
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<td></td>
<td></td>
<td>M4 Infraumbilical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M5 Suprapubic</td>
</tr>
<tr>
<td>- Lateral</td>
<td>Spiegel</td>
<td>L1 Subcostal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2 Flank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L3 Iliac</td>
</tr>
<tr>
<td></td>
<td>Lumbar</td>
<td>L4 Lumbar</td>
</tr>
<tr>
<td><strong>Transverse diameter</strong></td>
<td>Small &lt;2 cm</td>
<td>W1 ≤4 cm</td>
</tr>
<tr>
<td></td>
<td>Medium ≥2-4 cm</td>
<td>W2 ≥4-10 cm</td>
</tr>
<tr>
<td></td>
<td>Large &gt;4 cm</td>
<td>W3 &gt;10 cm</td>
</tr>
</tbody>
</table>

**Fig. 5**

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**Fig. 6:** European Hernia Society classification of middle-line and lateral incisional hernias.


**Fig. 7:** Direct inguinal hernia. Transversal image showing a fat protrusion through the hernia orifice (arrow), located medially to the deep inferior epigastric vessels (DIEV). The hernia displaces laterally the inguinal canal and its components (IC), forming the sign of the crescent (yellow-colored). CFV: common femoral vessels. DIH: direct inguinal hernia.
**Fig. 8:** Indirect inguinal hernia. Ileal loop herniated through the right inguinal ring (arrow). Deep inferior epigastric vessels (DIEV) are located lateral to the hernia. CFV: common femoral vessels.
Fig. 9: Femoral hernia. Transversal images showing an ileal loop in a hernia sac contacting the right common femoral vessels (CVF). B) The inguinal canal and its components (CI) displace anterior and medially the hernia sac (FH).

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**Fig. 10:** The diameters are precisely measured on a workstation following the axis of the abdominal wall.

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Fig. 11: Measuring multiple hernial orifice diameters located at adjacent areas. L: longitudinal diameter. T: transversal diameter.

**Fig. 12:** Middle-line epigastric hernia with jejunum loops inside. Transversal images in apnea (A) and during Valsalva’s maneuver, evidencing the increase in the hernial content, including transverse colon (*).  

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Fig. 13: Tranversal (A) and coronal (B) images of a follow-up study after a transverse colon tumor resection. The study during Valsalva´s maneuver (C and D) demonstrates a perineal hernia containing sigmoid colon.

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Fig. 14: Spiegelian hernia in the right iliac fossa containing several ileal loops with thickened walls due to vascular compromise.

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Fig. 15: Patient presenting with large right inguinoscrotal hernia and obstruction with vomiting and abdominal pain. In the transverse image (A) a herniated loop with pneumatosis (arrow) and abundant ectopic air in the hernia sac (*) secondary to ischemic necrosis and perforation of the strangulated loop is demonstrated. The proximal intestine is dilated (B) due to the obstruction caused by the bowel loop strangled.
Fig. 16: Patient with subxiphoid re-herniation after previous laparoscopic intervention. A) Three-dimensional reconstruction of the abdominal wall showing this defect. B and C) Sagittal and transversal images showing the metal fixations of the prosthesis. D) Coronal image shows a detachment of the prosthesis on the left side (*), which allows the intraperitoneal fat herniation (arrow).

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Fig. 17: Patient presenting in the immediate postoperative intense pain and decrease in hematocrit. The study demonstrates a large hematoma (*) between the prosthesis (arrow) and the peritoneum that displaces posteriorly the bowel loops.

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Fig. 18: Marked fatty atrophy of rectus abdominis (arrows). Rupture of right obliquus internus and transversus abdominis, and left transversus abdominis can be also observed.

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**Fig. 19:** Therapeutic pneumoperitoneum tranversal (A) and sagittal (B) images. Double supra and infraumbilical incisional hernia (arrows) can be seen in sagittal containing bowel loops and mesenteric fat.

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Fig. 20: The volume of both hernia and abdominal cavity can be calculated using semi-automated processes.

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Fig. 21: With this easy formula volumes can be also calculated using MDCT

Fig. 22: Vascular maximum intensity projection reconstructions. Deep inferior epigastric vessels arise from the external iliac arteries and are responsible for vascularization of the rectus abdominis and abdominal subcutaneous tissue.

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Fig. 23: Vascular studies of the abdominal wall allow identifying the epigastric vessels (A), knowing its intramuscular route (B) and locating the perforator vessels in the subcutaneous tissue (C and D). This information helps the intraoperative localization and prevents their injury.

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**Fig. 24:** The vascularization of the abdominal subcutaneous tissue depends on the perforating vessels of the epigastric arteries. The perforating vessels can be used as vascular pedicle flaps in reconstruction procedures. Vascular studies can identify these perforating vessels (A) and through a coordinate axis centered on the navel, locate them accurately (B and C) facilitating surgical dissection.

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Fig. 25: The elevated intraabdominal pressure caused by this previously unknown giant renal cyst facilitates the inguinal hernia appreciated (arrow).

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Fig. 26: A) Three-dimensional abdominal wall reconstruction showing contrast filled bowel loops inside the hernia sac. B) Oblique coronal image allows measuring the hernial orifice. C and D) Transversal and sagittal images showing the edge of the orifice and the hernial content.

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Conclusion

MDCT has a high sensitivity in the diagnosis of primary and incisional hernias of the abdominal wall. Its main indication is in cases where physical examination is difficult and cannot provide useful information by its own, but also MDCT gives relevant information in the herniary and postoperative complications.

MDCT provides high anatomical detail that allows assessing accurately hernial orifices, location, vascularization, size and content of the hernia. The information acquired by MDCT is useful to classify primary and incisional abdominal wall hernias, but also allows setting objective parameters for risk stratification and evaluating prognostic factors of relevance, such as abdominal muscles, which facilitate planning the best therapeutic option.

Thus, because of its availability, fast acquisition and capability to obtain multiplanar and three-dimensional functional images, MDCT has become the technique of choice not only in the diagnosis of complex cases, but also in the preoperative assessment of the more adequate surgical technique or approach and in the evaluation of complications. The possibility of performing dynamic studies (Valsalva and lateral decubitus) has been shown to increase diagnostic reliability and optimizes the information in the treatment decision making Fig. 28 on page 34.
PATIENT INFORMATION:

TECHNIQUE: CT Abdominal Wall protocol with oral contrast. 3D-reconstructions.

REPORT:

CLASSIFICATION: M1-M5, L1-L4, W1-W3

ORIFICE DIAMETERS: cm (AP, T and CC).

HERNIARY SAC DIAMETERS: cm (AP, T and CC).

HERNIARY SAC VOLUME: cc.

ABDOMINAL CAVITY VOLUME: cc

HERNIATED ABDOMINAL CONTENT (%):

HERNIARY SAC CONTENT: small intestine, colon, stomach, liver...

ABDOMINAL WALL MUSCLES: Atrophy, rupture.

OTHER ABDOMINAL WALL DEFECTS:

INGUINAL AREA:

Other findings:

CONCLUSION:

Fig. 28: This figure resumes the information that it is important for the clinician and that the radiological report must always include. It is based in our model of report.

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References