Acute Mesenteric Ischemia: The actual role of dual-energy CT and its future potential.

Award: Certificate of Merit
Poster No.: C-0666
Congress: ECR 2016
Type: Educational Exhibit
Authors: M. Nogueira¹, G. Tardáguila², D. Mera², M. Martínez², F. M. Tardaguila²; ¹Matosinhos/PT, ²Vigo/ES
Keywords: Ischemia / Infarction, Hemodynamics / Flow dynamics, Embolism / Thrombosis, Diagnostic procedure, CT, Small bowel, Emergency, Abdomen
DOI: 10.1594/ecr2016/C-0666

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

- To briefly review the clinical features, pathophysiology of mesenteric ischemia and physics of dual-energy CT.
- To describe and depict the CT findings of mesenteric ischemia highlighting the role of dual-energy CT on the diagnosis of this condition.

Background

Acute mesenteric ischemia is caused by insufficient blood flow through the mesenteric vessels which leads to ischemia and ultimately infarction of the intestinal wall.

It's a life-threatening condition in which an early diagnosis and treatment may make a difference.

Most of the patients are over 60 years old, it affects males and females equally, and has an estimated incidence of 12.9/100,000 person-years and a mortality rate of 50-90%.

ANATOMY

Three arteries supply blood to the small and large bowel; the celiac trunk, the superior mesenteric artery (SMA) and the inferior mesenteric artery (IMA).

*Celiac Trunk (Fig. 1 on page 9)*

The celiac trunk is responsible for the blood supply of the gastrointestinal tract from the distal esophagus to the descending duodenum. Three arteries arise from the celiac trunk: The left gastric artery, the splenic artery and the common hepatic artery, from which the gastroduodenal artery emerges and further anastomosis with the superior mesenteric artery.
**Fig. 1**: Celiac Trunk. (A) Gray's Anatomy 20th edition (1918) illustration and (B) Volume rendering CT scan reformation show celiac trunk (red arrow), common hepatic artery (green arrow), splenic artery (orange arrow), superior mesenteric artery (purple star) and gastroduodenal artery (blue arrow).

**References:** (A) Public Domain, in Gray's Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015

*Superior Mesenteric Artery (Fig. 2 on page 10)*

The superior mesenteric artery divides in the intestinal arteries which branch to the jejunum and ileum, the ileocolic artery which supplies the last part of ileum, cecum and appendix, the right colic artery to the ascending colon and the middle colic artery to the transverse colon. The marginal artery of Drummond and the arcade of Riolan are two relevant anastomotic connections to have in mind; the former is a continuous arterial circle along the inner border of the colon formed by the anastomoses of the terminal branches of the SMA and the IMA, and the latter is another vascular arcade that connects the proximal middle colic artery with a branch of the left colic artery.
Fig. 2: Superior and Inferior mesenteric arteries. (A) Gray’s Anatomy 20th edition (1918) illustration and (B) MIP CT scan reformation show superior mesenteric artery (purple arrow), inferior mesenteric artery (blue arrow), intestinal branches (green arrow), marginal artery of Drummond (black arrow), arcade of Riolan (orange arrow).

References: (A) Public Domain, in Gray’s Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015

**Inferior Mesenteric Artery** (Fig. 2 on page 10)

The inferior mesenteric artery branches to the left colic artery which supplies the descending colon, the sigmoid branches and the superior rectal artery forming several anastomoses to the lumbar branches of the abdominal aorta, the sacral artery, and the internal iliac arteries.

**Portal and Mesenteric Veins** (Fig. 3 on page 10)

The inferior mesenteric vein drains to the splenic vein which joins the superior mesenteric vein to form the portal vein. Anastomoses to gastric, esophageal, renal, lumbar and pelvic veins are important to keep in mind.
Fig. 3: Intestinal venous drainage. (A) Gray’s Anatomy 20th edition (1918) illustration and (B) MIP CT scan reformation show the inferior mesenteric vein (green arrow) draining into the splenic vein, which further joins the superior mesenteric vein (yellow arrow) to form the portal vein (red arrow).

References: (A) Public Domain, in Gray’s Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015

PATHOPHYSIOLOGY

The etiology of this disease is broad, ranging from arterial occlusion, venous occlusion, strangulation obstruction and non-oncclusive vascular disease in relation to low flow due to hypotension.

- Occlusion of the superior mesenteric artery accounts for approximately 60%-70% of the cases of acute intestinal ischemia. The etiology is vast but the two main mechanisms are thrombosis and thromboembolism.
- Mesenteric venous occlusion are responsible for about 5-10% of the cases. Common causes may be neoplastic infiltration, local inflammatory conditions as a gastrointestinal infection, pancreatitis or diverticulitis, hypercoagulation states as protein C or antithrombin III deficiencies, polycythemia vera, or peritoneal carcinomatosis. Impairment of the venous drainage leads to an elevation of the hydrostatic pressure, which may ultimately compromise the arterial blood flow and bowel infarction.
• Non-occlusive vascular disease represent about 20%-30% of the cases. It's related to low blood flow, and the etiology is extensive, from hemorrhagic shock, cardiac failure, dehydration to septic shock.

• Strangulation obstruction should also be borne in mind as a possible cause of ischemia.

Initially the ischemic damage is limited to the intestinal mucosa, it is reversible and consists on mucosal necrosis and erosions. As the ischemic damage progresses, necrosis extends to the submucosa and muscular layers, with consequent edema and hemorrhage. Pneumatosis intestinalis may further occur, indicating transmural infarction.

TREATMENT

TREATMENT and management of intestinal ischemia is beyond the purpose of this poster, nonetheless, it is important to acknowledge that recognition of acute mesenteric ischemia before permanent tissue damage occurs is the best way of improving patient survival.

Surgical revascularization is the treatment of choice for mesenteric ischemia, however thrombolytic medical treatment and vascular interventional radiological techniques have had a growing role in the past few years. If the ischemia progresses to the point that the affected intestinal segments are not savable, the therapeutic approach to transmural bowel infarction consists of surgical resection.

DUAL-ENERGY CT: HOW DOES IT WORK?

In dual-energy CT, two CT datasets are acquired with different x-ray spectra allowing characterization of different materials depending on their atomic number.

CT images are formed based on the attenuation of x-ray photons transmitted through the body. The two main photons interactions responsible for x-ray beam attenuation are the Compton scattering and Photoelectric effect (Fig. 4 on page 11).

• **Compton scattering** is the main cause of scattered radiation. It occurs due to the interaction of incident photons with the outermost shell electrons of the atoms. Compton scattering depends only on the electron density of a material.

• **Photoelectric effect** occurs when emitted photons have enough energy to interact and eject inner shell electrons (K-shell) of the atoms. The photoelectric effect is energy dependent and its probability of occurring increases as the energy of the incident photons approaches the K-shell binding energy.
Fig. 4: On the left, Compton scattering effect is shown, in which a photon interacts with an outer shell electron, resulting in a decrease in energy of the photon and a recoiling electron. On the right, photoelectric effect is depicted, showing the interaction and ejection of K-shell electron.

References: - Matosinhos/PT

Another important concept of dual-energy CT is the **K edge**. The term refers to the spike of attenuation that occurs at energy levels just greater than that of the K-shell binding value.

On figure 5 (Fig. 5 on page 12), the relation between attenuation and x-ray energy of two different substances is shown. One can note that as the x-ray energy increases, the attenuation expectedly decreases, however, when the x-ray energy approaches the K edge value of one of the substances, the attenuation suddenly increases due to the photoelectric effect in which photon energy is absorbed through the ejection of k shell electrons.
Fig. 5: Illustration shows elements A and B, which have K edges of 80 keV and 100 keV, respectively. The percentage of x-ray photon absorption is plotted as a function of x-ray energy.

References: - Matosinhos/PT

K-edge values vary for each element, and it’s based on that characteristic that dual-energy CT has the capacity of discriminating different materials.

<table>
<thead>
<tr>
<th>Substance</th>
<th>K Edge (keV)</th>
<th>Atomic Number (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.01</td>
<td>1</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.28</td>
<td>6</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.40</td>
<td>7</td>
</tr>
<tr>
<td>Calcium</td>
<td>4.00</td>
<td>20</td>
</tr>
<tr>
<td>Iodine</td>
<td>33.20</td>
<td>53</td>
</tr>
<tr>
<td>Barium</td>
<td>37.45</td>
<td>56</td>
</tr>
</tbody>
</table>
Fig. 6: K Edges and Atomic numbers of some substances.

References: - Matosinhos/PT

Hydrogen, carbon and nitrogen have K edge values too low and too similar to be differentiated with dual-energy CT. However, calcium, iodine and barium have K edge values high enough so that they may be distinguished from soft tissues at dual-energy imaging (Fig. 6 on page 13).

Currently the settings of 80 kVp and 140 kVp are the most commonly used. The K edge of iodine (33.2 keV) is closer to 80 kVp than to 140 kVp, and consequently iodine containing substances will show greater attenuation at lower energy levels resulting in an improved conspicuity between iodine-containing tissue and noniodine-containing tissue. Another advantages of dual-energy CT is the capacity to creating iodine material density images which allow better analysis of the differences in perfusion between tissues. Finally, dual energy CT has the capability of generating virtual unenhanced images avoiding the need for a separate unenhanced sequence as if conventional CT was performed, with the benefit of radiation dose reduction.

Images for this section:

Fig. 1: Celiac Trunk. (A) Gray's Anatomy 20th edition (1918) illustration and (B) Volume rendering CT scan reformation show celiac trunk (red arrow), common hepatic artery
(green arrow), splenic artery (orange arrow), superior mesenteric artery (purple star) and gastroduodenal artery (blue arrow).

© (A) Public Domain, in Gray’s Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015

Fig. 2: Superior and Inferior mesenteric arteries. (A) Gray’s Anatomy 20th edition (1918) illustration and (B) MIP CT scan reformation show superior mesenteric artery (purple arrow), inferior mesenteric artery (blue arrow), intestinal branches (green arrow), marginal artery of Drummond (black arrow), arcade of Riolan (orange arrow).

© (A) Public Domain, in Gray’s Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015
Fig. 3: Intestinal venous drainage. (A) Gray’s Anatomy 20th edition (1918) illustration and (B) MIP CT scan reformation show the inferior mesenteric vein (green arrow) draining in the splenic vein, which further joins the superior mesenteric vein (yellow arrow) to form the portal vein (red arrow).

© (A) Public Domain, in Gray’s Anatomy 20th edition (1918). (B) Department of Radiology, Hospital Povisa, Vigo, 2015
Fig. 4: On the left, Compton scattering effect is shown, in which a photon interacts with an outer shell electron, resulting in a decrease in energy of the photon and a recoiling electron. On the right, photoelectric effect is depicted, showing the interaction and ejection of K-shell electron.

© - Matosinhos/PT
**Fig. 5:** Illustration shows elements A and B, which have K edges of 80 keV and 100 keV, respectively. The percentage of x-ray photon absorption is plotted as a function of x-ray energy.

© - Matosinhos/PT

**Fig. 6:** K Edges and Atomic numbers of some substances.

© - Matosinhos/PT
Findings and procedure details

INTESTINAL ISCHEMIA AND DUAL-ENERGY CT

Technique

In our department when intestinal ischemia is suspected, CT scanning is performed in a SOMATOM Definition Flash Siemens dual source CT scan. An arterial phase is acquired 35 seconds after the injection of 120 mL of iopramide 300 with single energy at 120kVp. A venous phase at 70 seconds is then acquired with dual energy with 80 kVp and 140 kV. Dual energy images are later analysed in Siemens software Syngo.via.

CT Findings

CT findings in acute mesenteric ischemia may consist of various morphologic changes, including hypoattenuating intestinal wall, intestinal wall thickening, hyperattenuating intestinal wall, bowel lumen dilatation, mesenteric fat stranding, vascular engorgement, ascites, pneumatosis intestinalis, and portomesenteric gas.

Bowel wall hypoenhancement is the earliest CT sign and the one with higher specificity (93%–100%), which may often go unrecognized as the differences in contrast enhancement may be subtle.

As stated before, dual-energy CT can be useful as may improve early detection of bowel ischemia by increasing the conspicuity of hypoenhancing bowel segments on low-kiloelectron volt and iodine material density images.

Even though dual-energy CT use and accessibility is increasing progressively, investigation of potential benefits on the diagnosis of bowel ischemia has been limited.

Through the next cases, different causes of intestinal ischemia will be exposed and the advantages of dual-energy CT explored.

Case 1 - Arterial Occlusion
Figure 8-A (Fig. 7 on page 24) shows a CT scan of a 79 year-old patient who was admitted in the emergency department with abdominal pain. Faeculent material mingled with gas bubbles in the lumen of the small intestine could be seen, a finding which is suggestive of low-grade intestinal obstruction. No cause for obstruction could be noted and as the patient continued with abdominal pain after pain medication, acute intestinal ischemia was suspected and a dual-energy CT scan performed.

Fig. 7: (A) CT scan in a 79 year-old patient with abdominal pain showed faeculent material mingled with gas bubbles in the lumen of the small intestine (orange arrow. (B) Retrospectively, in this coronal MIP reconstruction, a distal SMA thrombosis was recognized (blue arrow), and could also be appreciated the difference in attenuation between the intestinal branches of the SMA on the left (orange dotted circle) compared to the right (green arrow).

References: Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

On Siemens syngo.via, iodine map images can be created. Standard CT attenuation values 80 kVp and 140 kVp are converted in a scale of greys; iodine material density is shown in a scale of reds in which lighter red correlates with a higher iodine content.

In figure 9 (Fig. 8 on page 25) , iodine map MIP reformation was done allowing one to clearly appreciate which areas of the intestine are in ischemia.
Fig. 8: Iodine map coronal MIP reformation shows area of ischemic intestine (white dotted circle) versus non-ischemic intestine (yellow dotted circle).

References: Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

Iodine content can be further quantified using ROI's as is shown in the image bellow (Fig. 9 on page 26).
Fig. 9: Iodine map coronal MPR (A) ROI in lighter red intestine wall shows a virtual noncontrast value of 16.7 HU, a postcontrast value of 54.2 HU, with an estimated increase in density in the order of 40 HU (yellow circle). On the other hand, darker red intestine wall shows a virtual noncontrast value of 29.9 HU, a postcontrast value of 25.7 HU, with an estimated increase in density in the order of -4.3 HU (green circle), compatible with ischemia. (B) On iodine map coronal MIP reformation, distal SMA thrombosis could be noted (green arrow).

References: Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

Case 2 - Venous Thrombosis

A 52-year old man was admitted in the emergency department of our institution with abdominal pain. A dual energy-CT scan was performed and acute intestinal ischemia due to portal vein and superior mesenteric vein thrombosis was diagnosed. Again, areas of ischemia could be better delineated than if a standard CT scan was done (Fig. 10 on page 27).
Fig. 10: On iodine map coronal MPR reformation one can better appreciate the ischemic intestinal segments (white dotted circle) versus well perfused segments (green dotted circle). Perihepatic ascites (red arrow) and extensive thrombosis of portal and superior mesenteric vein could also be seen (purple arrow).

**References:** Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

Iodine content was then quantified using ROI’s localized in the intestine wall. Non-ischemic intestine showed a mean increase in attenuation of about 30 to 40 HU. Ischemic intestinal wall had no increase in attenuation (-11 to 2.3 HU) (Fig. 11 on page 29).

![Iodine map coronal MPR](image)

Fig. 11: Iodine map coronal MPR. ROI’s in viable intestine showed a mean increase in attenuation of about 30 to 40 H (yellow boxes). Ischemic intestinal wall showed no increase in attenuation (-11 to 2.3 HU) (green boxes). The attenuation of the intestinal wall on virtual noncontrast was between 45-51 HU.

**References:** Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

It was also noted that the attenuation of the intestinal wall in virtual noncontrast was between 45-51 HU. On virtual noncontrast images it was possible to see that the wall of the ischemic intestinal segment was slightly hyperdense, which added to the attenuation value of around 50 HU, was compatible with intestinal wall hemorrhage (Fig. 12 on page 29).
**Fig. 12**: On virtual noncontrast image, the ischemic intestinal wall is slightly hyperdense and has around 50 HU, compatible with intestinal wall hemorrhage. **References:** Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

On surgery, this findings could be confirmed and the difference between ischemic and nonischemic segments clearly recognized.
**Fig. 13**: Ischemic segments (darker red), could be clearly demarcated from viable bowel (lighter red).

**References**: Department of General Surgery, Hospital Povisa, Vigo, Spain, 2015

**Case 3 - Arterial and Venous Thrombosis**

80-year old man was admitted in emergency department with severe abdominal pain.

At dual-energy CT scan images it could be seen hypoenhancement of a large portion of the small bowel wall and pneumatosis intestinalis of the proximal colon, traducing intestinal infarction. The ischemic areas could be clearly depicted due to the use of coronal iodine map MPR reformations (Fig. 14 on page 31).

There was severe superior mesenteric artery atherosclerosis and thrombosis of the distal third of the mesenteric artery and vein (Fig. 15 on page 32).
Fig. 15: Iodine map coronal MIP reformation. It may be seen superior mesenteric artery atherosclerosis and thrombosis of the distal third of the mesenteric artery (green star) and thrombosis of superior mesenteric vein (green arrow).

References: Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

Case 4 - Non-oncclusive vascular disease
79-year old man was admitted in emergency department with diffuse abdominal pain. He was dehydrated and anemic, with a hemoglobin of 8.6 g/dl.

At the dual-energy CT scan images it could be identified cecum and ascending colon wall hypoenhancement and pneumatosis intestinalis, traducing intestinal infarction (Fig. 16 on page 33).

**Fig. 16:** On iodine map, pneumatosis intestinalis could be seen (blue arrow), and cecum ischemia recognized. ROI in cecum intestine wall showed a mean increase in contrast of 7 HU (white box), suggestive of ischemia.

**References:** Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

There were no signs of mesenteric arteries or veins thrombosis, therefore, ischemia was attributed to hypoperfusion due to anemia and low blood flow. On surgery, the previous
findings were confirmed and it was performed a subtotal colectomy (Fig. 17 on page 33).

**Fig. 17**: On iodine map coronal MIP reformation it can be appreciated that portal vein, superior mesenteric vein and superior mesenteric artery are permeable. Pneumatosis intestinalis is also shown (blue arrow).

**References**: Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

**Images for this section:**
Fig. 7: (A) CT scan in a 79 year-old patient with abdominal pain showed faeculent material mingled with gas bubbles in the lumen of the small intestine (orange arrow). (B) Retrospectively, in this coronal MIP reconstruction, a distal SMA thrombosis was recognized (blue arrow), and could also be appreciated the difference in attenuation between the intestinal branches of the SMA on the left (orange dotted circle) compared to the right (green arrow).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
Fig. 8: Iodine map coronal MIP reformation shows area of ischemic intestine (white dotted circle) versus non-ischemic intestine (yellow dotted circle).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
**Fig. 9:** Iodine map coronal MPR (A) ROI in lighter red intestine wall shows a virtual noncontrast value of 16.7 HU, a postcontrast value of 54.2 HU, with an estimated increase in density in the order of 40 HU (yellow circle). On the other hand, darker red intestine wall shows a virtual noncontrast value of 29.9 HU, a postcontrast value of 25.7 HU, with an estimated increase in density in the order of - 4.3 HU (green circle), compatible with ischemia. (B) On iodine map coronal MIP reformation, distal SMA thrombosis could be noted (green arrow).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
Fig. 10: On iodine map coronal MPR reformation one can better appreciate the ischemic intestinal segments (white dotted circle) versus well perfused segments (green dotted circle). Perihepatic ascites (red arrow) and extensive thrombosis of portal and superior mesenteric vein could also be seen (purple arrow).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

Fig. 11: Iodine map coronal MPR. ROI’s in viable intestine showed a mean increase in attenuation of about 30 to 40 H (yellow boxes). Ischemic intestinal wall showed no increase in attenuation (-11 to 2,3 HU) (green boxes). The attenuation of the intestinal wall on virtual noncontrast was between 45-51 HU.

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
Fig. 12: On virtual noncontrast image, the ischemic intestinal wall is slightly hyperdense and has around 50 HU, compatible with intestinal wall hemorrhage.

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
Fig. 13: Ischemic segments (darker red), could be clearly demarcated from viable bowel (lighter red).

© Department of General Surgery, Hospital Povisa, Vigo, Spain, 2015
Fig. 14: Iodine map coronal MPR reformations. (A) Discrimination between darker red ischemic areas (yellow dotted line) and lighter red viable bowel (green dotted line) may be easily done. One could note proximal colon pneumatosis intestinalis (blue arrow). (A-C) ROI's in lighter red intestinal wall (green circles) show a mean increase in attenuation between 27 and 44 HU, compatible with viable bowel. ROI's in darker red intestinal bowel wall (yellow circles) show a mean increase in attenuation between -10 and 11 HU, in relation with ischemia.

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
**Fig. 15:** Iodine map coronal MIP reformation. It may be seen superior mesenteric artery atherosclerosis and thrombosis of the distal third of the mesenteric artery (green star) and thrombosis of superior mesenteric vein (green arrow).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015

**Fig. 16:** On iodine map, pneumatosis intestinalis could be seen (blue arrow), and cecum ischemia recognized. ROI in cecum intestine wall showed a mean increase in contrast of 7 HU (white box), suggestive of ischemia.

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
**Fig. 17:** On iodine map coronal MIP reformation it can be appreciated that portal vein, superior mesenteric vein and superior mesenteric artery are permeable. Pneumatosis intestinalis is also shown (blue arrow).

© Department of Radiology, Hospital Povisa, Vigo, Spain, 2015
Conclusion

In 1930, Cokkinis stated "Occlusion of the mesenteric vessels is to be regarded as one of those conditions of which the diagnosis is impossible, the prognosis hopeless, and the treatment almost useless".

85 years later medicine changed astonishingly in an unpredictable way.

We believe dual-energy CT may improve early detection of bowel ischemia by increasing the conspicuity of hypoenhancing bowel segments, allowing an earlier intervention, greater salvage of the bowel, and consequently a lower mortality.

Personal information

Miguel Nogueira
ULS Matosinhos, Matosinhos, Portugal

e-mail: miguelfnog@gmail.com

References
