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TRANSORAL ROBOTIC SURGERY (TORS): SETUP AND BASICS

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Over the last two decades the use of surgical robots has become increasingly commonplace. Initial reports of using robots to assist in surgical procedures date to the mid-1980's with rapid technological evolution in computing and robotics since that time. While first widely adopted in the field of general surgery, use of the surgical robot has spread to almost all other surgical subspecialties.

Transoral robotic surgery (TORS) has become a widely accepted approach to provide minimally invasive access to the upper aerodigestive tract. In parallel with such surgical innovation, the shift in epidemiology of oropharyngeal squamous cell carcinoma and increased incidence of human papillomavirus (HPV)-related disease has renewed interest in comparing surgical and nonsurgical treatments as well as treatment deintensification. In this context, TORS has been widely adopted in many high-resource settings as a first-line surgical treatment for selected oropharyngeal tumours of the palatine and lingual tonsils and base of tongue.

TORS reduces surgical morbidity substantially when compared to open surgical approaches to the oropharynx, and for properly selected patients, may offer long-term functional advantages relative to chemoradiotherapy strategies. TORS has expanded to include surgical procedures of the larynx and hypopharynx and has been applied to a wide array of both benign and malignant pathologies.

The main disadvantage of TORS is the substantial cost of acquiring and maintaining the surgical robot. In addition, a lack of haptic (tactile) feedback for the operating surgeon is a major limitation, although haptic feedback systems are being investigated for integration into future robotic systems.

Robot Basics

Surgical robots function by remote operation or teleoperation, in which the surgeon controls the robot's movements in real-time. There is no robotic autonomy during TORS – the surgeon dictates and carries out all aspects of the procedure. Most platforms employ a binocular endoscope with a high-definition camera and several robotic arms that are positioned in the patient's mouth to establish the field of view and to access the area of concern. Rather than moving surgical instruments with his/her hands, the surgeon sits at a separate console and directs the movement of the robotic arms and surgical instruments *(Figure 1)*.

Figure 1. Surgeon sits at a separate console and directs movements of the robotic arms and surgical instruments

Several commercially available surgical robots are in use in an ever-expanding array of procedures across numerous surgical specialties. The most widely used surgical robot is the da Vinci® system manufactured by *Intuitive Surgical, Inc* (Sunnyvale, CA). It uses a *leader-follower* teleoperation architecture which relies on an electronic computerized intermediary between the surgeon control interface (*leader*) and surgical instruments (*follower*). The surgeon manipulates controls at a console that in turn mobilises surgical arms on the robot to mimic the surgeon's movements.

While an in-depth comparison of surgical robotic systems is beyond the scope of this chapter, it is nonetheless important for the reader to be aware that an array of robotic systems of several generations are currently in use. At the authors' institution, the da Vinci Si robotic system is used to perform TORS procedures and will be shown in the photographs below. From a technical standpoint, the da Vinci system offers high-definition (720-1080p), high-magnification (10-15x), and 3-dimensional visualisation of the surgical field. As compared to human hands, robotic instruments have improved manual dexterity and precision with seven degrees of freedom (i.e. angled instrumentation, suprahuman range of motion, tremor filtration, and motion scaling).

Intuitive Surgical has released several newer generations of surgical robots including the Xi and SP systems. Like its predecessor, the da Vinci Xi system has four surgical arms that are more compact and mounted to an overhead boom with more flexible joints for improved ergonomics and access. This system has not been approved by the Food and Drug Administration (FDA) for use in the United States in otolaryngology. The da Vinci SP, a single-port robotic system, has also demonstrated effectiveness for use in a limited set of TORS procedures with FDA approval in 2019.

The da Vinci system has 3 distinct components: a) Surgeon console, b) Patient cart, and c) Vision cart.

Surgeon Console *(Figures 2a - e)*

The surgeon sits at the Surgeon Console and operates the robotic instruments using a set of ***surgical controllers*** which operate like joysticks. Each of these controllers is operated with two fingers, allowing the surgeon's hand motions to be scaled and translated electronically to accomplish precise surgical tasks.

Figure 2a: Surgeon Console

The surgeon views the operating field through a high-definition ***stereo viewer*** that provides 3-dimensional binocular vision. A ***footswitch panel*** with various pedals at the surgeon's feet allows for activation of instruments such as cautery.

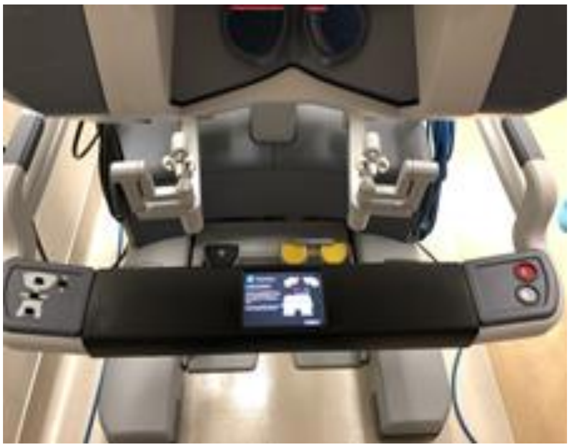


Figure 2b: Surgeon Console

Figure 2c: Master Controller

Figure 2d: Stereo Viewer

Figure 2e: Footswitch Panel

Patient Cart *(Figure 3)*

This constitutes the actual operative robot. It has four surgical arms. The arms are initially positioned by pressing various clutch buttons allowing for motion at the arms' multiple joints.

Figure 3a: Patient Cart

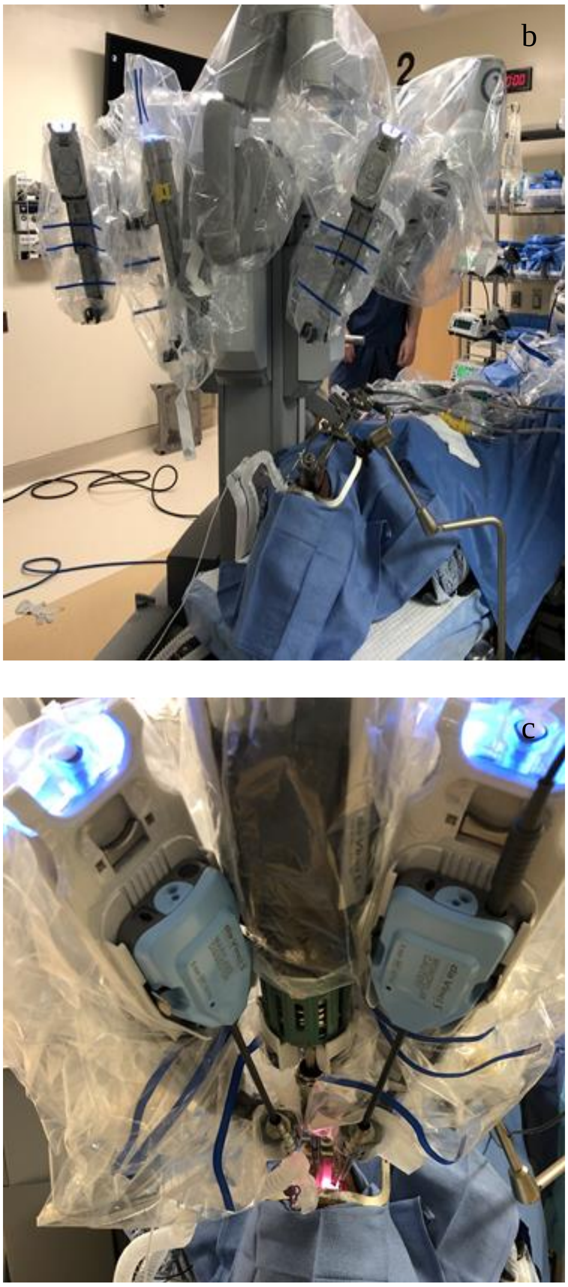
Three of the robotic arms can hold instruments, with the 4th designated for the surgical endoscope. However, in TORS procedures, typically only three (camera arm and two instrument arms) of the four surgical arms are used due to the narrow transoral surgical corridor. Cannulas must be mounted into the distal aspect of the instrument arms to facilitate placement of actual surgical instruments. Instruments have seven degrees of freedom allowing for marked nimbleness in small spaces.

Typically, the surgical endoscope is placed centrally in the mouth with one effector arm on each side. A dissecting instrument is typically positioned contralateral to the lesion/tumour to maximise retraction with a suction cautery or clip applier positioned in the ipsilateral arm (*Figures3 b,c)*.

The Da Vinci SP uses a single-port 2.5cm cannula with three working instruments and a fully wristed endoscope that rotates 360 degrees. The addition of a 3rd working arm allows for traction and countertraction to be simultaneously applied during dissection.

Vision Cart *(Figure 4)*

The vision cart enables system integration and contains critical electronic components including the light source for the robotic endoscope, camera connections for the endoscope, as well as a cautery/electrosurgical unit(s). A two-dimensional screen at the top of the cart displays the operative field and is used by the assistant during surgery. Markings may be made by the supervising surgeon or assistant using the touchscreen interface and may be seen in real-time by the console surgeon.



Figures 3 b,c: Patient Cart: Surgical robot appears with sterile draping and three surgical arms are seen entering into the oral cavity (centrally-positioned surgical endoscope with adjacent instrumented arms)

Figure 4: Vision Cart

Figure 5a: Maryland Dissector

Figure 5b: Monopolar Cautery

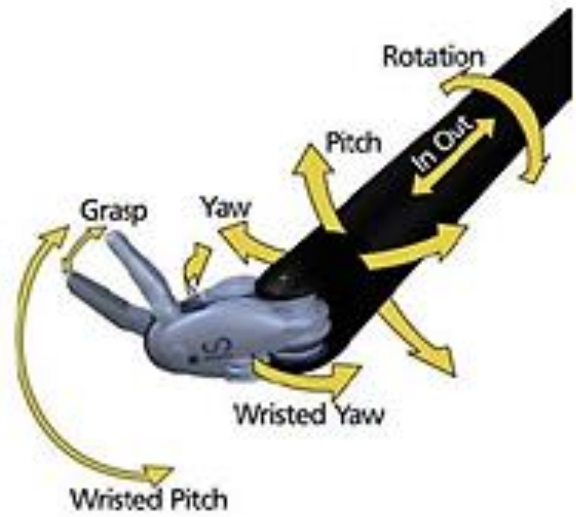


Figure 5c: Degrees of Freedom

Robotic Instruments *(Figure 5)*

The robotic arms of the patient cart operate using surgical instruments which are manipulated by the surgeon via the master controllers. Robotic instruments have impressive dexterity allowing for a greater range of motion than the human hand. A variety of standard surgical instruments are available to allow the surgeon to grasp, dissect, cauterise, and suture. Commonly used instruments for TORS procedures include the Maryland retractor and monopolar electrocautery *(Figures 5a,b).*

Instruments are rotated via a center of axis identified on their respective trocars to avoid inadvertent trauma to the patient. The da Vinci instruments can be reused for only a limited number of procedures after which they are discarded and replaced.

Endoscope/Camera *(Figure 6)*

The robotic endoscope enables visualization of the operative field by mounting it on a camera head. Like traditional endoscopes, the robotic endoscope is available in various angles to facilitate visualization. Both 0-degree and 30-degree endoscopes can be used for TORS, most frequently for tonsil and base of tongue procedures, respectively. The Da Vinci SP uses a fully wristed endoscope, allowing for a broader range of visualization.

Figure 6: Zero-degree robotic endoscope with sterile draping

Transoral Robotic Surgery

Equipment and Instruments

A variety of equipment and materials are used in TORS. The following list, while not comprehensive, includes commonly used equipment that is included for TORS setups at many institutions.

- Mouth gag: Crowe-Davis [*Medline*, Illinois, USA], Feyh-Kastenbauer [*Gyrus Medical Inc*, Tuttlingen, Germany], Flex retractor [*Medrobotics*, Massachusetts, USA], Dingman retractor, etc. *(Figures 7a-d)*
- Standard suction monopolar electrocautery
- Suspension stand
- Standard paediatric Yankauer and velvet-eye suction
- Surgical robot
- Robotic surgical endoscopes (0-degree and 30-degree)
- Robotic instruments, most commonly spatula-tip monopolar cautery and Maryland dissector *(Figures 5a,b)*

In addition to the above equipment which is used for the robotic part of a case, many TORS procedures are done concurrently with a neck dissection. In such cases, it is our practice to have a separate sterile table for soft tissue instrumentation as is appropriate.

Figure 7a: Crowe-Davis retractor (without tongue blades)

Figure 7b: Dingman retractor

Figure 7c: Flex retractor

Figure 7d: Feyh-Kastenbauer retractor

Personnel

It is important to have a well-trained team to perform TORS safely and efficiently. At many high-volume institutions performing robotic surgery, a team of specialty-trained circulating nurses and surgical technologists are designated for robotic cases. Such an institutional investment relies on case volume and organisational resources and may not be feasible at all institutions. Establishing dedicated robot-specific support personnel enables achievement of subject matter/domain expertise allowing for streamlined room setup and the ability to skillfully troubleshoot issues in real time.

Below is a description of the roles played by individuals during TORS surgical cases:

- **Head Surgeon:** Sits at the surgeon console and manipulates the master controllers to perform the surgery. Note that the head surgeon is located at a distance away from the patient and is not next to the patient during the procedure *(Figure 8).*

Figures 8a,b: Head surgeon seated at the Surgeon Console operating the surgical robot. Surgeon is located remote to surgical field and is unable to directly visualize the patient or robotic arms/ instruments while operating

- **Surgical Assistant:** Seated at the head of the OR bed throughout the surgery. Manages non-robotic instruments required during surgery including suction, standard (non-robotic) monopolar suction cautery, etc. The surgical assistant actively provides critical exposure by retracting surrounding soft tissues and evacuating smoke during the dissection. The assistant often obtains haemostasis at the end of the procedure with monopolar suction cautery and assists in placement of tissue sealants or haemostatic agents in the surgical bed. Because this individual is at the patient's bedside, he/she also ensures that no physical harm or collisions are inadvertently caused by the robot (i.e., no unwanted dental contact, trauma to the lips, etc). This role is often filled by a surgical resident or advanced practice provider *(Figure 9).*

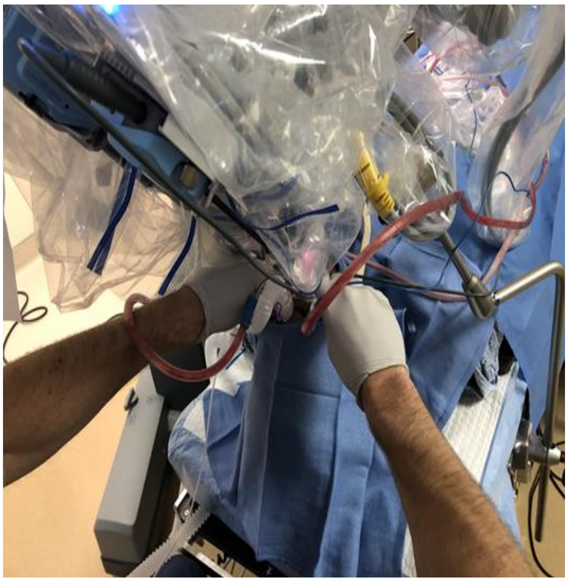


Figure 9: Surgical assistant seated at the head of the bed. From this vantage point the assistant must also monitor the movement of surgical arms and instruments to ensure no undue harm to the patient

- **Anaesthesiologist:** Administers and manages general anaesthesia

- **Surgical Technologist:** Must have a strong knowledge of robotic components. Primarily responsible for setting up the patient/vision carts and additional equipment that will be needed. Present at the operative field during surgery.

- **Circulating Nurse:** Needs a strong knowledge about robotic components. Assists surgical tech during setup and should be able to drive the patient cart into position for docking. Is the member of the team with the most mobility during surgery to help troubleshoot.

OR Setup/Configuration *(Figure 10)*

There are variations regarding the exact configuration of equipment and personnel for TORS. Because the upper aerodigestive tract is a small, difficult-to-access anatomic area, the operative field around the patient's head is naturally crowded.

The surgical assistant sits at the patient's head facing the patient. The robot is docked at a 30-degree angle to the side of the patient. At our institution we dock the robot to the patient's left side with the vision cart placed on the patient's right side. This allows the bedside surgical assistant an unencumbered view of the operative screen and optimises the surgeon's view of the patient and robotic setup when not looking through the stereo viewer on the surgeon console. Because of the numerous instruments and personnel already occupying the region around the patient's chest and head, the locations of anaesthetic equipment and the anaesthesia team vary by institution, determined by available space. *Figure 10* demonstrates the OR configuration during TORS procedures at our institution.

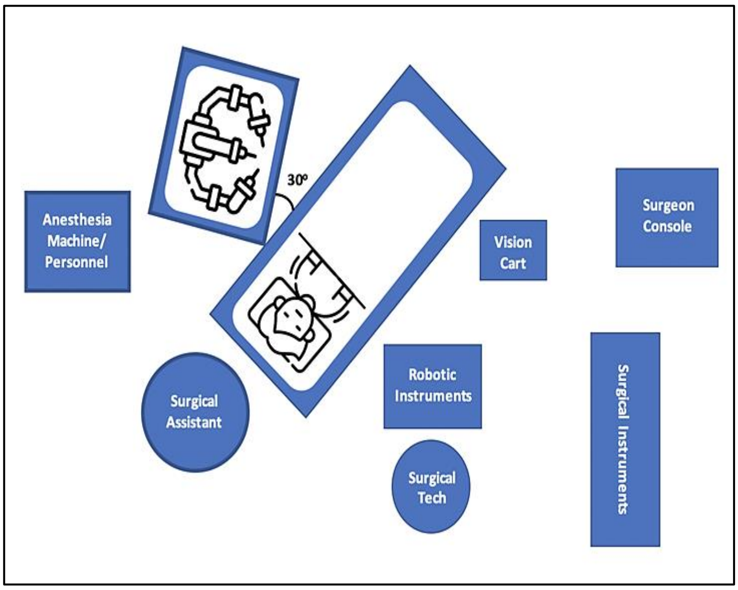


Figure 10: Diagram of OR layout at our institution. While this arrangement may vary at other institutions, it is standard to have the assistant at the head of bed, robot on patient's side, anaesthesiology on the patient's side, and head surgeon/console often off to the side of the OR, remote from the patient

Intubation

Because TORS of the upper aerodigestive tract involves surgical manipulation in very tight anatomic spaces adjacent to critical structures, the anaesthetic plan and patient positioning merit specific consideration. Standard orotracheal intubation with a small endotracheal tube is commonly employed when operating on the palatine tonsils and hypopharynx. However, it is our preference to perform nasotracheal intubation (standard endotracheal tube or nasal RAE tube) for TORS procedures involving the lingual tonsils/base of tongue or larynx to improve surgical exposure. To reduce pressure and risk of inadvertent nasal alar injury, we trim a standard nasal sponge (e.g. Merocel) to several centimeters in length and slide it along the medial/superior aspect of the nasotracheal tube to reduce pressure on the nasal ala and septum *(Figures 11a-c)*.

Figure 11a-c: Adjunct safety measures commonly employed during TORS: Merocel® or other nasal packing can be trimmed *to protect the nasal septum/ala during nasal intubation; Hard fox shields are placed over the eyes to minimize risk of inadvertent ocular injury; AquaplastTM splinting material can be fashioned as a dental guard in dentulous patients*

Eye and Dental Protection *(Figure 11)*

Protecting dentition is critical. Depending on the retractor system (Medrobotics Flex or FK), we recommend custom moulding of an Aquaplast splint to fit the upper and lower dentition as it is rigid, durable, and lower profile than standard rubber mouthguards. A splint is unnecessary when a Crowe-Davis retractor is used as it has a soft rubber pad that cushions the patient's teeth.

Because of the high number of instruments around the patient's head, protecting the eyes is critical. Some centers place hard plastic eye protection such as Optigard (Dupaco, California, USA) goggles or fox eye shields onto patients undergoing TORS. It is also important that close attention is paid to the eyes throughout the procedure to avoid any inadvertent eye injury.

Exposure

One of the most challenging aspects of any TORS procedure is to establish a satisfactory view of the anatomic region and lesion planned for surgical resection. While establishing adequate exposure can be time consuming, it is critical not to rush this part of the procedure.

Appropriate anaesthesia is the first step to surgical exposure as this is a key to procedure safety and affects the degree of mouth opening. Patients undergoing TORS must be totally immobilised before attempting exposure or entry of the robotic arms into the surgical field as even small movements can cause serious injury against the rigid, fixed mechanical components of a retractor or robotic instruments. We recommend paralysis as an essential component of general anaesthesia for TORS to reduce inadvertent movement and to optimise mouth opening.

Several retraction and suspension systems are available for TORS *(Figure 7a-d)*. Both the Crowe-Davis and McIvor tonsil gags have been adapted for use with TORS. Tonsil gags are familiar to otolaryngologists and offer excellent visualisation and access to the tonsillar pillars. Crowe-Davis and McIvor tonsil gags are standardly used for TORS radical tonsillectomy and other lateral oropharyngeal procedures.

However, these gags offer limited visibility of the tongue base, hypopharynx, and larynx. Alternate retractors are therefore commonly used for TORS in which these structures need to be exposed. The Feyh-Kastenbauer (FK) retractor is commonly used, as is the Dingman retractor. The Medrobotics Flex retractor is another commonly used retraction system but is no longer commercially available *(Figure 12)*. The FK, Dingman, and Flex retractors use a variety of tongue blades and offer three-dimensional adjustment capability that improve robotic visualisation and access to the tongue base and below.

Figure 12 demonstrates a standard TORS setup for base of tongue resection using the Medrobotics Flex system. Anterior distraction (stretching the base of tongue) is critical for exposure of the tongue base. Hence, in addition to nasotracheal intubation and use of the aforementioned retractors, we place a ***single retraction suture through the back half of the oral tongue*** 1-2cms anterior to the circumvallate papillae, to pull the tongue forward before the retractions system is introduced.

Figure 12: Patient undergoing TORS in suspension using the Medrobotics Flex® retraction system. Patient can be seen to be nasally intubated with black silk retraction suture through the oral tongue

Additional Safety Considerations

Because TORS involves movement of heavy equipment, it is of the utmost importance to thoughtfully employ safety precautions and protect the delicate structures of the head and neck. Particular attention should be paid to avoid inadvertent injury to the patient when inserting or withdrawing instruments from the oral cavity. The surgical assistant and surgical tech are well positioned to supervise movement of instruments around the patient.

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Additional Open Access Resources

Videos demonstrating TORS setup for tonsil and base of tongue resection:

- Transoral Robotic Surgery Set Up - American Head & Neck Society (ahns.info)
- https://www.ahns.info/resources/education/video/transoral-robotic-surgery-set-up/

Transoral Robotic Surgical (TORS) approaches to Parapharyngeal Space, Hypopharynx and Larynx: https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Transoral%20Robotic%20Surgical%20_TORS_%20%20approaches%20to%20Parapharyngeal%20Space%2C%20Hypopharynx%20and%20Larynx.pdf

Transoral Robotic Oropharyngectomy (TORS) surgical technique for cancers of the tonsil and base of tongue: https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Transoral%20Robotic%20Oropharyngectomy%20_TORS_%20surgical%20technique%20for%20cancers%20of%20the%20tonsil%20and%20base%20of%20tongue.pdf

Transoral Robotic Thyroidectomy (TORT) and Robotic Facelift Thyroidectomy (RFT): https://vula.uct.ac.za/access/content/group/ba5fb1bd-be95-48e5-81be-586fbaeba29d/Transoral%20Robotic%20Thyroidectomy%20_TORT_%20and%20Robotic%20Facelift%20Thyroidectomy%20_RFT_.pdf

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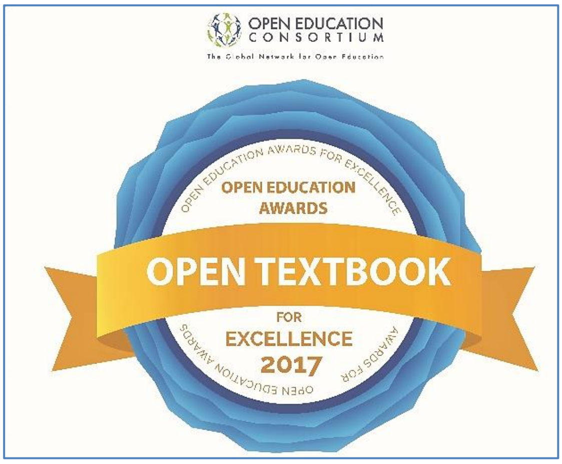
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