We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Ultrasound-Guided Brachytherapy for Cervical Cancer - A Tool for Quality Improvement in Brachytherapy?

Ekkasit Tharavichitkul and Razvan M. Galalae

Abstract

Nowadays, brachytherapy is one of the major components to treat inoperable cervical cancer. Brachytherapy yields a higher dose to the target (cervix) while sparing normal tissues. Developments of brachytherapy stepped forward in the previous decade by image-guided brachytherapy (IGBT) turning brachytherapy from point-based planning to volume-based planning and IGBT improves the treatment quality for cervical cancer. Magnetic resonance imaging (MRI) or computed tomography (CT) is utilized in brachytherapy and showed promising results internationally. However, in a limited-resource area, the implementation of IGABT is difficult due to many causes (manpower, equipment, or budgets). To improve the quality in limited resources, ultrasound is introduced. The utilization of ultrasound in brachytherapy practice is to prevent uterine perforation during application. With present data, measurement by ultrasound showed the correlation to MRI measurement in uterine dimensions. With these aspects, there are many researches using ultrasound to improve the quality of treatment in brachytherapy, for example, to guide contouring on CT or to support brachytherapy planning. The use of ultrasound improves the quality of brachytherapy in comparison to conventional planning and supports the improvement in brachytherapy for cervical cancer.

Keywords: brachytherapy, cervical cancer, ultrasound

1. Introduction

Cervical cancer is one of the most common cancers among the female population with the fourth most common after breast, colorectal, and lung cancer. In 2018, there were approximately 570,000 new cases of cervical cancer with 311,000 deaths [1]. Treatment of cervical cancer is composed of surgery, radiotherapy and systemic treatment. Concurrent chemoradiation is the standard treatment for locally advanced cervical cancer (LACC) and the combination of external beam radiotherapy (EBRT) and brachytherapy (BT) maximizes the local control while minimizing the risk of toxicity. Standard EBRT should deliver a dose of 45–50.4 Gy to the whole pelvis encompassing the uterus, adnexal structures, parametria, and pelvic lymph nodes. With BT, various dose fraction schedules are used, applying a dose of 5.5–8 Gy by 3–5 fractions and the total combined dose with EBRT and BT should be in the range of 80–90 Gy [2]. From the publications of Han et al. and

Gill et al. BT is one of the major components for curative radiotherapy for LACC [3–5]. Completion of the radiation program within a suitable time is an important goal as it has a direct correlation to the outcome. The current recommendation is to finish the entire protocol of EBRT and BT within 8 weeks [2].

2. Point-based brachytherapy for cervical cancer

Brachytherapy was used to increase the curative dose to cervical cancer from the year when Todd and Meredith et al. introduced the Manchester system with radium [6, 7]. The using of point A, bladder point, and rectum point (identified in orthogonal X-rays) were reported with ICRU 38 concepts [8, 9]. The intrauterine tandem and intravaginal applicators were used in many institutes to treat cervical cancer, with acceptable results. **Figure 1** shows orthogonal X-rays for conventional planning.

Figure 1. Point A (black triangle), point B (white circle), ICRU bladder (black star), ICRU rectum (white star) and 5-mm vagina points (black circle) from The Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

3. Volume-based IGBT for cervical cancer

The concepts of volume-based brachytherapy in magnetic resonance imaging (MRI) started by the publications of the Groupe Européen de Curietherapie and the European Society for Radiotherapy and Oncology GEC-ESTRO in 2005–2006 to propose the definitions of targets (high-risk clinical target volume; HR-CTV and intermediate-risk clinical target volume; IR-CTV) and normal tissues (Organs at risk (OARs); bladder, rectum and sigmoid) with dose constraints for evaluation [10, 11]. Moreover, the additional concepts of HR-CTV were extrapolated to CT since 2007 and developed to many international publications [12–15]. **Figure 2** shows the HR-CTV and IR-CTV according to GEC-ESTRO recommendations.

In comparison to conventional brachytherapy (point A), IGBT keeps the cumulatively curative dose to the target (HR-CTV) while sparing the cumulative dose to normal tissues [16–19]. After the first clinical results of IGBT were reported by Pötter et al. in 2007, many institutes started to develop IGBT around the world [20]. The selected publications of IGBT are shown in **Table 1** and shown promising results in local control and toxicity.

Figure 2. HR-CTV and IR-CTV on MRI and CT related to GEC-ESTRO recommendations from the division of radiation oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

Studies	N	Imaging	FU time	LC	Gr 3-4 Toxicities
Pötter et al. [21]	156	MRI	42 months	95%	11 events
Lindeggaard et al. [22]	140	MRI	36 months	91%	1%(GU), 3%(GI)
Sturdza et al. [23]	731	MRI > > CT	43 months	91%	5% GU, 7% GI, 5% vagina
Tinkle et al. [24]	111	MRI with IPSA	42 months	94%	8%
Castelnau-Marchand et al. [25]	225	MRI	38.8 months	86.4%	6.6%
Mahanshetty et al. [26]	94	MRI	39 months	90.1%	3% (GU), 9%(GI)
Murakami et al. [27]	51	CT	39 months	91.7%	2% (GI)
Ohno et al. [28]	80	CT	60 months	94%	1% (GU)
Tharavichitkul et al. [29]	47	CT	26 months	97%	2.1%(GU) 2.1% (GI)
Pötter et al. [30]	1341	MRI	51 months	92%	6.8% (GU), 8.5% (GI)

BT, brachytherapy, CT, computed tomography, GI, gastrointestinal toxicity, GU, genitourinary toxicity, MRI, magnetic resonance imaging, IPSA, inverse planning simulated annealing.

Table 1.
 Selected studies of IGBT.

4. Clinical results of ultrasound in brachytherapy for cervical cancer

Ultrasound in medicine was firstly developed by the military (as “sonar”) and was firstly investigated in the 1940s by the method of echo-reflection to detect tumors, exudates, or abscesses [31]. Ultrasound developed very much in obstetrics and gynecology to evaluate the growing fetus and examinations in gynecological conditions [32]. Using ultrasound in clinical practice of brachytherapy divides into three aspects a) applicator guidance, b) CT-based contouring, and c) planning process. The most common use of ultrasound in brachytherapy for cervical cancer is to guide insertion of intrauterine tandem to prevent uterine perforation. Although, in this era, the incidence of uterine perforation was 3% from Segedin et al. [33]. The use of ultrasound can support accurate and safe application in brachytherapy procedures in cervical cancer. Moreover, ultrasound can help the practitioner to adjust the applicator to be a suitable position before patient transportation to the next steps. **Figure 3** shows uterine perforation by TAUS.

Figure 3. Uterine perforation during insertion by TAUS from The Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

Studies	N	Modality	Findings
Van Dyk et al. [40]	2	TAUS	TAUS is portable, nonexpensive, and simple to use and allows for accurate, conformal, re-producible, and adaptive treatments.
Van Dyk et al. [34]	71	TAUS	TAUS plan in comparison to two-dimensional MRI image was comparable for target volume ($p = 0.11$), rectal point ($p = 0.8$), and vaginal mucosa ($p = 0.19$). Local control was 90%. Late GI toxicity was less than 2%.
Mahanshetty et al. [43]	20	TAUS	TAUS correlated with MR in evaluating uterus, cervix, and central disease for IGBT.
Van Dyk et al. [35]	192	TAUS	The mean differences between TAUS and two-dimensional MRI images were less than 3 mm in the cervix. The mean differences were less than 1.5 mm at all measurement points on the posterior surface.
Narayan et al. [42]	292	TAUS	At median FU time of 41 months, 5-yr overall survival rate was 65%.
Schmid et al. [44]	19	TRUS	TRUS is better than CT as it produces systematically smaller deviations from MRI, with good to excellent image quality.
Van Dyk et al. [41]	191	TAUS	At median FU time of 5.3 years, 5-yr overall survival rate was 63%. Late toxicities were 3% for GI, 1.6% for GU, and 2% for vagina.
Mahanshetty et al. [37]	25	TRUS	CT-based delineation using MRI at diagnosis and TRUS during BT seems comparable with MRI-based approach in IGBT for cervical cancer.
Tharavichitkul et al. [45]	92	TAUS	At median FU time of 41 months, pelvic control rate was 84.8%.

BT, brachytherapy; CT, computed tomography; FU, follow up; GI, gastrointestinal; GU, genitourinary; IGBT, image-guided brachytherapy; MRI, magnetic resonance imaging; TAUS, transabdominal ultrasound; TRUS, transrectal ultrasound.

Table 2. Selected studies showed progression of US guidance in brachytherapy.

To guide CT-based contouring is very new for using ultrasound. This comes from the pain point of CT-based contouring is an overestimation in comparison to MRI-based contouring [12]. To find the support equipment, some researchers found that the US in transabdominal (TAUS) or transrectal (TRUS) approaches showed a correlation in measurement with MRI [34–37]. Moreover, the publication from Schmid et al. showed TRUS is superior to CT as it yields systematically smaller deviations from MRI, with good to excellent image quality [38] and Mahanshetty et al. published the correlation of MRI-based contouring versus CT-based contouring supported by TRUS [37]. In recently, the latest publication from IBS-GEC ESTRO-ABS recommended TRUS to support CT-based contouring in IGBT for cervical cancer [39].

The use of TAUS in the planning process was firstly developed by Peter MacCallum Cancer Center, Melbourne, Australia [40]. This process developed from the measurement by TAUS showed a correlation to MRI [35]. In Peter MacCallum Cancer Center, the cooperation of TAUS and MRI (in first application) supported the high-end treatment in brachytherapy for cervical cancer. With this implementation, international publications were reported to support TAUS in brachytherapy [34, 35, 40, 41]. In 2014, they published a survival outcome that showed a 5-year overall survival rate of 65% [42].

The developments of US guidance for brachytherapy are concluded in **Table 2**.

5. Experiences of TAUS-guided brachytherapy in the division of radiation oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University

In the Faculty of Medicine, Chiang Mai University, TAUS-guided was implemented 10 years ago to support the conventional brachytherapy during the transformation process from 2D to 3D brachytherapy since 2011. The concepts of TAUS-guided brachytherapy were adapted from Van Dyk et al. [34, 40]. From our process, we performed brachytherapy as an outpatient basis. The workflow of our procedure is shown in **Figure 4**.

After walk-in, patients were adjusted to lithotomy position and skin preparation was performed. Then, Foley’s application was performed and at least 200 ml of NSS were filled into the bladder to improve the image quality of TAUS. TAUS was performed during uterine sound and intrauterine tandem applications to prevent uterine perforation. After the application finished, TAUS was performed to measure the dimension of the cervix. Eight measurements (L1-L4 and A1-A4) of cervix dimensions (from intrauterine tandem to the uterine wall) were performed (sagittal

Figure 4.
Workflow of TAUS-based brachytherapy.

Figure 5.

Measurements in sagittal and axial views by TAUS from The Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

and transverse approaches) at the level of the cervical OS, and 2 cm cranially to the cervical OS, adapted from previous work by Van Dyk et al. [40]. **Figure 5** shows the measurement of the cervix by TAUS.

The planning processes of TAUS-guided brachytherapy in our institute were defined as the two methods for delivering TAUS measurements into treatment planning software. When we started TAUS-guided brachytherapy in 2011, conventional brachytherapy by orthogonal X-rays was utilized by the PLATO workstation. At that time, an indirect process (to transfer the measurements from TAUS to the orthogonal X-ray) was performed. After we installed the new Oncentra workstation in 2014, a direct process (to import the DICOM images of TAUS in sagittal view to the workstation) adapted from Peter MacCallum Cancer center [34, 42] was developed to use in our patients. After applicator reconstruction by manual process or applicator library, the eight dimensions were generated to be eight cervix reference points correlated to intrauterine tandem in lateral and anteroposterior view. **Figure 6** shows the cervix reference points in the sagittal view of ultrasound sound.

After generation of eight cervix reference points, dwell weight or time was optimized to achieve a sufficiently minimal dose to the cervix reference points of at least prescribed dose (6–7 Gy per fraction). **Figure 7** shows dose distribution by TAUS.

From our experiences, TAUS-guided brachytherapy improved the dose to the normal tissues. It reduced the cumulative overdose to the bladder (>80 Gy) and rectum (>75 Gy) in comparison to standard point A treatment and our intermediate-term results showed the 2-year local control of 88% [45]. From 2012 to 2018, more than 100 patients were treated with this technique. Nowadays, after CT was installed in our brachytherapy unit in 2019, we totally transformed to 3D (volume-based) brachytherapy. We still use TAUS to evaluate proper placement and support our CT contouring.

Figure 6.
TAUS images showed cervix reference points (black star) in sagittal view from The Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

Figure 7.
Isodose distribution for TAUS-guided brachytherapy for cervical cancer (red line is 100% of prescribed dose that focus on the first 2 centimeter of uterus) from The Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, Chiang Mai University.

However, TAUS still has some limitations in patients who cannot have a full bladder (cystostomy or vesicovaginal fistula), and the concept of TAUS in adaptive treatment is still on point-based planning (e.g., cervix reference points). The concept of volume-based approaches via 3D ultrasound is pending [31]. However, TAUS is inexpensive, portable, non-ionizing, and real-time equipment. TAUS supports application safely, CT contouring, and planning itself. TAUS encourages treatment quality in low-resource and high-workload centers to propose improvement in conventional brachytherapy (point A) to adaptive point-based planning (adaptive plan to cervix reference points; 2.5D). Further studies in ultrasound in CT-based contouring and planning should be performed to support the alternatives for brachytherapy in place in which MRI or CT are inaccessible.

6. Conclusion

Although trends of brachytherapy turned from point-based to volume-based plans via MRI or CT, not all cancer centers can access this equipment. To improve the quality of the point-based plan, ultrasound supports the whole process of

brachytherapy, for example, applicator insertion, CT-based contouring, and planning process. TAUS-guided brachytherapy shows promising results by international publications and the cost of TAUS is cheap, and portable. Ultrasound can be applied to all levels of the cancer center to improve the quality of brachytherapy.

Acknowledgements

The author offers many thanks to all staff of the Division of Radiation Oncology, Department of Radiology, Faculty of Medicine, and Chiang Mai University for supporting all works.

Conflict of interest

The authors declare no conflict of interest.

Author details

Ekkasit Tharavichitkul^{1,2*} and Razvan M. Galalae^{3,4}

1 Faculty of Medicine, The Division of Radiation Oncology, Department of Radiology, Chiang Mai University, Chiang Mai, Thailand

2 Faculty of Medicine, Northern Thailand Radiation Oncology Group, Department of Radiology, Chiang Mai University, Chiang Mai, Thailand

3 MedAustron Ion Therapy Center, Wiener Neustadt, Austria

4 Faculty of Medicine, Christian-Albrechts-University, Kiel, Germany

*Address all correspondence to: ekkasit.t@cmu.ac.th

IntechOpen

© 2021 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

- [1] Arbyn M, Weiderpass E, Bruni L, de Sanjosé S, Saraiya M, Ferlay J, et al. Estimates of incidence and mortality of cervical cancer in 2018: A worldwide analysis. *The Lancet Global Health*. 2020;**8**:e191-e203. DOI: 10.1016/S2214-109X(19)30482-6
- [2] Bhatla N, Aoki D, Sharma DN, Sankaranarayanan R. Cancer of the cervix uteri. *International Journal of Gynecology & Obstetrics*. 2018;**143**: 22-36. DOI: 10.1002/IJGO.12611
- [3] Han K, Milosevic M, Fyles A, Pintilie M, Viswanathan AN. Trends in the utilization of brachytherapy in cervical cancer in the United States. *International Journal of Radiation Oncology, Biology, Physics*. 2013;**87**:111-119. DOI: 10.1016/j.ijrobp.2013.05.033
- [4] Gill BS, Lin JF, Krivak TC, Sukumvanich P, Laskey RA, Ross MS, et al. National cancer data base analysis of radiation therapy consolidation modality for cervical cancer: The impact of new technological advancements. *International Journal of Radiation Oncology, Biology, Physics*. 2014;**90**: 1083-1090. DOI: 10.1016/j.ijrobp.2014.07.017
- [5] Tanderup K, Eifel PJ, Yashar CM, Pötter R, Grigsby PW. Curative radiation therapy for locally advanced cervical cancer: Brachytherapy is NOT optional. *International Journal of Radiation Oncology, Biology, Physics*. 2014;**88**:537-539. DOI: 10.1016/j.ijrobp.2013.11.011
- [6] Tod MC, Meredith WJ. A dosage system for use in the treatment of cancer of the uterine cervix. *The British Journal of Radiology*. 1938;**11**:809-824. DOI: 10.1259/0007-1285-11-132-809
- [7] Tod M, Meredith WJ. Treatment of cancer of the cervix uteri, a revised Manchester method. *The British Journal of Radiology*. 1953;**26**:252-257. DOI: 10.1259/0007-1285-26-305-252
- [8] Chassagne D, Dutreix A, Almond P, Burgers JMV, Busch M, Joslin CA. 2. Definition of Terms and Concepts Currently Used in Intracavitary Therapy. *Journal of the International Commission on Radiation Units and Measurements*. 1985;**os-20**:4-8. DOI: 10.1093/jicru_os20.1.4
- [9] Chassagne D, Dutreix A, Almond P, Burgers JMV, Busch M, Joslin CA. 3. Recommendations for Reporting Absorbed Doses and Volumes in Intracavitary Therapy. *Journal of the International Commission on Radiation Units and Measurements*. 1985;**os-20**: 9-14. DOI: 10.1093/jicru_os20.1.9
- [10] Haie-Meder C, Pötter R, Van Limbergen E, Briot E, De Brabandere M, Dimopoulos J, et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): Concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV. *Radiotherapy and Oncology*. 2005;**74**: 235-245. DOI: 10.1016/j.radonc.2004.12.015
- [11] Pötter R, Haie-Meder C, Van Limbergen E, Barillot I, De Brabandere M, Dimopoulos J, et al. Recommendations from gynaecological (GYN) GEC ESTRO working group (II): Concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy - 3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology. *Radiotherapy and Oncology*. 2006;**78**:67-77. DOI: 10.1016/j.radonc.2005.11.014
- [12] Viswanathan AN, Dimopoulos J, Kirisits C, Berger D, Pötter R. Computed tomography versus magnetic resonance imaging-based contouring in cervical

cancer brachytherapy: Results of a prospective trial and preliminary guidelines for standardized contours. *International Journal of Radiation Oncology*. 2007;**68**:491-498

[13] Viswanathan AN, Erickson B, Gaffney DK, Beriwal S, Bhatia SK, Lee Burnett O, et al. Comparison and consensus guidelines for delineation of clinical target volume for CT- and MR-based Brachytherapy in locally advanced cervical cancer. *International Journal of Radiation Oncology*. 2014;**90**:320-328

[14] Ohno T, Wakatsuki M, Toita T, Kaneyasu Y, Yoshida K, Kato S, et al. Recommendations for high-risk clinical target volume definition with computed tomography for three-dimensional image-guided brachytherapy in cervical cancer patients. *Journal of Radiation Research*. 2017;**58**:341-350. DOI: 10.1093/jrr/rrw109

[15] Mahantshetty U, Gudi S, Singh R, Sasidharan A, Sastri S, Gurram L, et al. Indian Brachytherapy Society Guidelines for radiotherapeutic management of cervical cancer with special emphasis on high-dose-rate brachytherapy. *Journal of Contemporary Brachytherapy*. 2019;**11**:293-306. DOI: 10.5114/jcb.2019.87406

[16] De Brabandere M, Mousa AG, Nulens A, Swinnen A, Van Limbergen E. Potential of dose optimisation in MRI-based PDR brachytherapy of cervix carcinoma. *Radiotherapy and Oncology*. 2008;**88**:217-226. DOI: 10.1016/j.radonc.2007.10.026

[17] Tharavichitkul E, Mayurasakorn S, Lorvidhaya V, Sukthomya V, Wanwilairat S, Lookaew S, et al. Preliminary results of conformal computed tomography (CT)-based intracavitary brachytherapy (ICBT) for locally advanced cervical cancer: A single Institution's experience. *Journal*

of Radiation Research. 2011;**52**:634-640. DOI: 10.1269/jrr.10154

[18] Tharavichitkul E, Sivasomboon C, Wanwilairat S, Lorvidhaya V, Sukthomya V, Chakrabhandu S, et al. Preliminary results of MRI-guided brachytherapy in cervical carcinoma: The Chiangmai University experience. *Journal of Radiation Research*. 2012;**53**:313-318. DOI: 10.1269/jrr.11107

[19] Tharavichitkul E, Wanwilairat S, Chakrabandhu S, Klunklin P, Onchan W, Tippanya D, et al. Image-guided brachytherapy (IGBT) combined with whole pelvic intensity-modulated radiotherapy (WP-IMRT) for locally advanced cervical cancer: A prospective study from Chiang Mai University Hospital, Thailand. *Journal of Contemporary Brachytherapy*. 2013;**5**:10-16. DOI: 10.5114/jcb.2013.34338

[20] Pötter R, Dimopoulos J, Georg P, Lang S, Waldhäusl C, Wachter-Gerstner N, et al. Clinical impact of MRI assisted dose volume adaptation and dose escalation in brachytherapy of locally advanced cervix cancer. *Radiotherapy and Oncology*. 2007;**83**:148-155. DOI: 10.1016/j.radonc.2007.04.012

[21] Pötter R, Georg P, Dimopoulos JCA, Grimm M, Berger D, Nesvacil N, et al. Clinical outcome of protocol based image (MRI) guided adaptive brachytherapy combined with 3D conformal radiotherapy with or without chemotherapy in patients with locally advanced cervical cancer. *Radiotherapy and Oncology*. 2011;**100**:116-123. DOI: 10.1016/j.radonc.2011.07.012

[22] Lindegaard JC, Fokdal LU, Nielsen SK, Juul-Christensen J, Tanderup K. MRI-guided adaptive radiotherapy in locally advanced cervical cancer from a Nordic perspective. *Acta Oncologica (Madr)*. 2013;**52**:1510-1519. DOI: 10.3109/0284186X.2013.818253

- [23] Sturdza A, Pötter R, Fokdal LU, Haie-Meder C, Tan LT, Mazon R, et al. Image guided brachytherapy in locally advanced cervical cancer: Improved pelvic control and survival in RetroEMBRACE, a multicenter cohort study. *Radiotherapy and Oncology*. 2016;**120**:428-433. DOI: 10.1016/j.radonc.2016.03.011
- [24] Tinkle CL, Weinberg V, Chen L-M, Littell R, Cunha JAM, Sethi RA, et al. Inverse planned high-dose-rate Brachytherapy for locoregionally advanced cervical cancer: 4-year outcomes. *International Journal of Radiation Oncology, Biology, Physics*. 2015;**92**:1093-1100. DOI: 10.1016/j.ijrobp.2015.04.018
- [25] Castelnau-Marchand P, Chargari C, Maroun P, Dumas I, Del Campo ER, Cao K, et al. Clinical outcomes of definitive chemoradiation followed by intracavitary pulsed-dose rate image-guided adaptive brachytherapy in locally advanced cervical cancer. *Gynecologic Oncology*. 2015;**139**:288-294. DOI: 10.1016/j.ygyno.2015.09.008
- [26] Mahantshetty U, Krishnatry R, Hande V, Jamema S, Ghadi Y, Engineer R, et al. Magnetic resonance image guided adaptive Brachytherapy in locally advanced cervical cancer: An experience from a tertiary cancer center in a low and middle income countries setting. *International Journal of Radiation Oncology, Biology, Physics*. 2017;**99**:608-617. DOI: 10.1016/j.ijrobp.2017.06.010
- [27] Murakami N, Kobayashi K, Shima S, Tsuchida K, Kashiwara T, Tselis N, et al. A hybrid technique of intracavitary and interstitial brachytherapy for locally advanced cervical cancer: Initial outcomes of a single-institute experience. *BMC Cancer*. 2019;**19**:221. DOI: 10.1186/s12885-019-5430-x
- [28] Ohno T, Noda SE, Okonogi N, Murata K, Shibuya K, Kiyohara H, et al. In-room computed tomography-based brachytherapy for uterine cervical cancer: Results of a 5-year retrospective study. *Journal of Radiation Research*. 2017;**58**:543-551. DOI: 10.1093/jrr/rrw121
- [29] Tharavichitkul E, Chakrabandhu S, Wanwilairat S, Tippiya D, Nobnop W, Pukanhaphan N, et al. Intermediate-term results of image-guided brachytherapy and high-technology external beam radiotherapy in cervical cancer: Chiang Mai University experience. *Gynecologic Oncology*. 2013;**130**:81-85. DOI: 10.1016/j.ygyno.2013.04.018
- [30] Pötter R, Tanderup K, Schmid MP, Jürgenliemk-Schulz I, Haie-Meder C, Fokdal LU, et al. MRI-guided adaptive brachytherapy in locally advanced cervical cancer (EMBRACE-I): A multicentre prospective cohort study. *The Lancet Oncology*. 2021;**22**:538-547. DOI: 10.1016/S1470-2045(20)30753-1
- [31] van Dyk S, Khaw P, Lin MY, Chang D, Bernshaw D. Ultrasound-guided Brachytherapy for cervix cancer. *Clinical Oncology*. 2021;**33**:e403-e411. DOI: 10.1016/j.clon.2021.02.011
- [32] Campbell S. A short history of sonography in obstetrics and gynaecology. *Facts, Views & Vision in ObGyn*. 2013;**5**:213-229
- [33] Segedin B, Gugic J, Petric P. Uterine perforation - 5-year experience in 3-d image guided gynaecological brachytherapy at institute of oncology ljubljana. *Radiology and Oncology*. 2013;**47**:154-160. DOI: 10.2478/raon-2013-0030
- [34] Van Dyk S, Narayan K, Fisher R, Bernshaw D. Conformal Brachytherapy Planning for Cervical Cancer Using Transabdominal Ultrasound. *International Journal of Radiation Oncology, Biology, Physics*. 2009;**75**:64-70. DOI: 10.1016/j.ijrobp.2008.10.057

- [35] Van Dyk S, Kondalsamy-Chennakesavan S, Schneider M, Bernshaw D, Narayan K. Comparison of measurements of the uterus and cervix obtained by magnetic resonance and transabdominal ultrasound imaging to identify the brachytherapy target in patients with cervix cancer. *International Journal of Radiation Oncology, Biology, Physics*. 2014;**88**:860-865. DOI: 10.1016/j.ijrobp.2013.12.004
- [36] Umesh M, Kumar DP, Chadha P, Choudary R, Kembhavi S, Thakur M, et al. Transabdominal ultrasonography-defined optimal and definitive bladder-filling protocol with time trends during pelvic radiation for cervical cancer. *Technology in Cancer Research & Treatment*. 2017;**16**:917-922. DOI: 10.1177/1533034617709596
- [37] Mahantshetty U, Naga CHP, Khadanga CR, Gudi S, Chopra S, Gurram L, et al. A prospective comparison of computed tomography with transrectal ultrasonography assistance and magnetic resonance imaging-based target-volume definition during image guided adaptive Brachytherapy for cervical cancers. *International Journal of Radiation Oncology, Biology, Physics*. 2018;**102**:1448-1456. DOI: 10.1016/j.ijrobp.2018.05.080
- [38] Schmid MP, Nesvacil N, Pötter R, Kronreif G, Kirisits C. Transrectal ultrasound for image-guided adaptive brachytherapy in cervix cancer – An alternative to MRI for target definition? *Radiotherapy and Oncology*. 2016;**120**:467-472. DOI: 10.1016/j.radonc.2016.01.021
- [39] Mahantshetty U, Poetter R, Beriwal S, Grover S, Lavanya G, Rai B, et al. IBS-GEC ESTRO-ABS recommendations for CT based contouring in image guided adaptive brachytherapy for cervical cancer. *Radiotherapy and Oncology*. 2021;**160**:273-284. DOI: 10.1016/j.radonc.2021.05.010
- [40] Van Dyk S, Bernshaw D. Ultrasound-based conformal planning for gynaecological brachytherapy. *Journal of Medical Imaging and Radiation Oncology*. 2008;**52**:77-84. DOI: 10.1111/j.1440-1673.2007.01917.x
- [41] van Dyk S, Narayan K, Bernshaw D, Kondalsamy-Chennakesavan S, Khaw P, Lin MY, et al. Clinical outcomes from an innovative protocol using serial ultrasound imaging and a single MR image to guide brachytherapy for locally advanced cervix cancer. *Brachytherapy*. 2016;**15**:817-824. DOI: 10.1016/j.brachy.2016.07.008
- [42] Narayan K, van Dyk S, Bernshaw D, Khaw P, Milesshkin L, Kondalsamy-Chennakesavan S. Ultrasound guided conformal brachytherapy of cervix cancer: Survival, patterns of failure, and late complications. *Journal of Gynecologic Oncology*. 2014;**25**:206-213. DOI: 10.3802/jgo.2014.25.3.206
- [43] Mahantshetty U, Khanna N, Swamidass J, Engineer R, Thakur MH, Merchant NH, et al. Trans-abdominal ultrasound (US) and magnetic resonance imaging (MRI) correlation for conformal intracavitary brachytherapy in carcinoma of the uterine cervix. *Radiotherapy and Oncology*. 2012;**102**:130-134. DOI: 10.1016/j.radonc.2011.08.001
- [44] Mahantshetty U, Sturdza A, Naga CHP, Berger D, Fortin I, Motisi L, et al. Vienna-II ring applicator for distal parametrial/pelvic wall disease in cervical cancer brachytherapy: An experience from two institutions: Clinical feasibility and outcome. *Radiotherapy and Oncology*. 2019;**141**:123-129. DOI: 10.1016/j.radonc.2019.08.004

[45] Tharavichitkul E, Chakrabandhu S, Klunklin P, Onchan W, Jia-Mahasap B, Wanwilairat S, et al. Intermediate-term results of trans-abdominal ultrasound (TAUS)-guided brachytherapy in cervical cancer. *Gynecologic Oncology*. 2018;**148**:468-473. DOI: 10.1016/j.ygyno.2018.01.015

IntechOpen

IntechOpen