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Conventional radiotherapy planning of cervical cancer in resource-constrained set-up: Utilizing soldering lead wire to delineate radiotherapy portal

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ABSTRACT

Simulator for radiotherapy planning may not be available in resource-constrained set-up. Surface anatomy based planning has its own limitation in terms of adequately covering target due to variation of anatomy and tumor growth and spread pattern. Hence, improvisation of radiotherapy planning of cervical cancer, commonest malignancy among women in this set-up, utilizing locally available resource may improve treatment quality.

Soldering lead wire, plumber's measuring tape, diagnostic x-ray and transpore adhesive tape were utilized to delineate radiotherapy portals for management of cervical cancer. Delineation of radiotherapy portals for irradiation of different regions in selected patients of carcinoma cervix is feasible in resource-constrained set-up. Radiotherapy delivery by conventional 2-D technique through the portal designed by utilizing soldering lead wire and diagnostic x-ray was achievable. Radiotherapy portal so delineated need to be validated in future clinical studies.

1. Background

80% of global burden and mortality of cervical cancer occurs in developing countries and radiotherapy is the mainstay of treatment of this malignancy (Sherris et al., 2001; Thakur et al., 2013). X-ray simulator is the basic requirement for planning radiotherapy of cervical cancer by conventional technique (either 2-field AP/PA or 4-field box technique). X-ray simulator may still be expensive, difficult to maintain due to logistics and servicing issues in developing countries. Delineation of 2-field parallel opposed AP/PA radiotherapy portals that is recommended for conventional radiotherapy planning is dependent on bony anatomical landmarks and is possible only with the availability of x-ray simulator. In the absence of simulator, modification of diagnostic x-ray machine to perform x-ray simulation for brachytherapy planning of carcinoma cervix has been achieved (Ravichandran et al., 2018; Bhabha Atomic Research Centre (BARC), 2020; Kumar et al., 2016). Hence, there is a need to develop technique for radiotherapy planning utilizing locally available resources.

2. Methods

Soldering lead wire, plumber's metal measuring tape, diagnostic x-ray equipment and transpore adhesive tape were utilized to delineate radiotherapy portals in our study.

2.1. Informed consent

Informed consent was obtained from all the patients for radiotherapy planning and treatment. Current manuscript presents the real-world data of management of carcinoma cervix in resource-constrained set-up. Consent was obtained from all the patients planned and treated in our centre. The informed consent was basic requirement for all the patients willing to undergo radiation therapy. The same for radiotherapy was obtained after explaining the patients of outcome of disease based on results of published literature on management of cervical cancer by conventional radiotherapy technique in an out-patient setting.

2.2. Preliminary radiotherapy portals

AP/PA/lateral portal was marked on corresponding body surface using bony and soft-tissue landmark for the following radiotherapy portals with patient in supine position.

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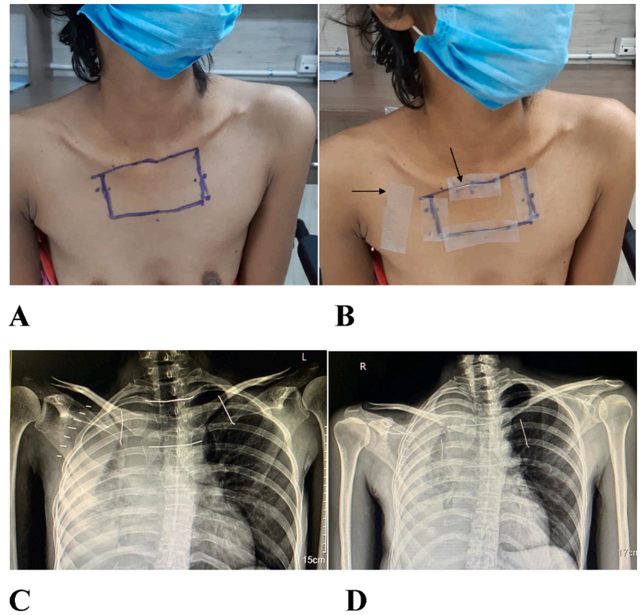

Fig. 2. Figure depicts effect of position during diagnostic x-ray simulation in a patient of advanced/metastatic gynecologic cancer planned for mediastinal irradiation by conventional technique. (A) Points on Supra-sternal notch or upper border of manubrium sterni, at a distance of 4 cms on either side of midline of body and manubrio-sternal junction (angle of Louis) were superior, lateral and inferior borders respectively of preliminary radiotherapy portals for irradiation of superior mediastinum. (B) Placing of soldering lead wire over these borders (marked by vertical arrow) and customized lead scale over right anterior chest wall (marked by horizontal arrow) and precede diagnostic x-ray simulation. (C & D) Diagnostic x-ray simulation in standing and supine position respectively: Difference in position of customized scale and soldering lead wire placed over borders of radiotherapy portal can be observed. Gross error in finalizing radiation portal may arise if x-ray simulation is done in position that is different from preliminary and treatment position. Also right border of mediastinum is difficulty to make out in view of right sided large pleural effusion. Taking image in rotated position. i.e. patient rotating to right side is the reason for non-appearence of mediastinal shadow on left side of mid-line of chest. Error may creep in by non-reproduction of position and mal-position during any of preliminary marking, diagnostic x-ray simulation or radiation treatment on teletherapy equipment.

2.3. Pelvic portal

Lower border was marked beyond vaginal introitus over upper thighs. Highest point of iliac crest corresponded with L4 vertebrae and a projection of this point over anterior abdominal wall marked the upper border. Points at 8cms on either side of midline of body were marked and vertical line was drawn through these points connecting upper and lower border. These vertical lines formed lateral border of parallel opposed AP/PA pelvic radiotherapy portals (Fig. 1).

2.4. Para-aortic portal

If indicated para-aortic portal is delineated by drawing horizontal line 0.5 cm above the upper border of pelvic portal. Upper border at mid-point between xiphi-sternum and umbilicus. Kidneys are the critical normal structures that have to be excluded from this radiotherapy portal. Hence, points at 4cms on either side of midline was marked and vertical line was drawn through these points connecting upper and lower border (Fig. 1).

2.5. Mediastinal portal

Pulp of the index finger is gently moved over anterior surface of sternum from suprasternal notch to identify manubrio-sternal joint. Moving laterally from manubrio-sternal joint to identify lower border of second rib. A horizontal line passing through midline of body and joining lower border of right and left second rib is the lower border. A point 1 cm above the suprasternal notch/upper border of manubrium sterni was marked and horizontal line was drawn on either side passing through this point on midline of body. Points at 5 cms on either side of mid-line is marked and vertical line was drawn passing through these points connecting upper and lower border (Fig. 2).

2.6. Supraclavicular portal

Junction of medial 2/3 and lateral 1/3 of clavicle is identifies. Vertical line 1 cm lateral to this point is drawn both above and below the clavicle. A horizontal line from mid-point of manubrio-sternal angle is drawn laterally to join the vertical line. Horizontal line 0.5 cm above and paralle to the upper border of cricoid cartilage marks the upper border of this portal (Fig. 3).

2.7. Whole and partial brain radiotherapy portal

Lower border is marked by drawing an oblique line from outer canthus of eye to the tragus of ipsilateral ear. Anterior border is marked by vertical line drawn upwards over forehead from the level of pupil while the patient looks straight anteriorly. Free fall of upper and posterior border in the air above and behind outer table of skull respectively completes the cranial radiotherapy portal. Measurement of distance between outer table of frontal bone at the level of forehead and anterior-most, posterior-most extent of tumour and distance between outer table of occipital bone at the level of occipital protuberance and posterior extent of tumour as observed in axial section of CT scan is used to delineate anterior and posterior border of partial brain irradation portal. Distance between outer table of vertex to superior-most and inferior-

Fig. 1. Conventional radiotherapy planning (delineation of portal) for pelvic and para-aortic irradiation. A. Positron Emission Tomography (PET) image of patient of carcinoma cervix with conglomerate para-aortic lymphadenopathy B. Preliminary skin marking of pelvic and para-aortic fields on anterior surface of torso and upper thigh C. Supine AP x-ray of pelvis obtained after placing customized scale in x-ray FOV and soldering lead wire over border of preliminary pelvic radiotherapy portal D. Supine AP x-ray of abdomen obtained after placing customized scale in x-ray FOV and soldering lead wire over border of preliminary para-aortic lymph nodal radiotherapy portal. Borders of preliminary pelvic and para-aortic radiotherapy portals were moved in x- and y-axes based on the measurement obtained by x-ray markings of customized scale (on the right side of midline).

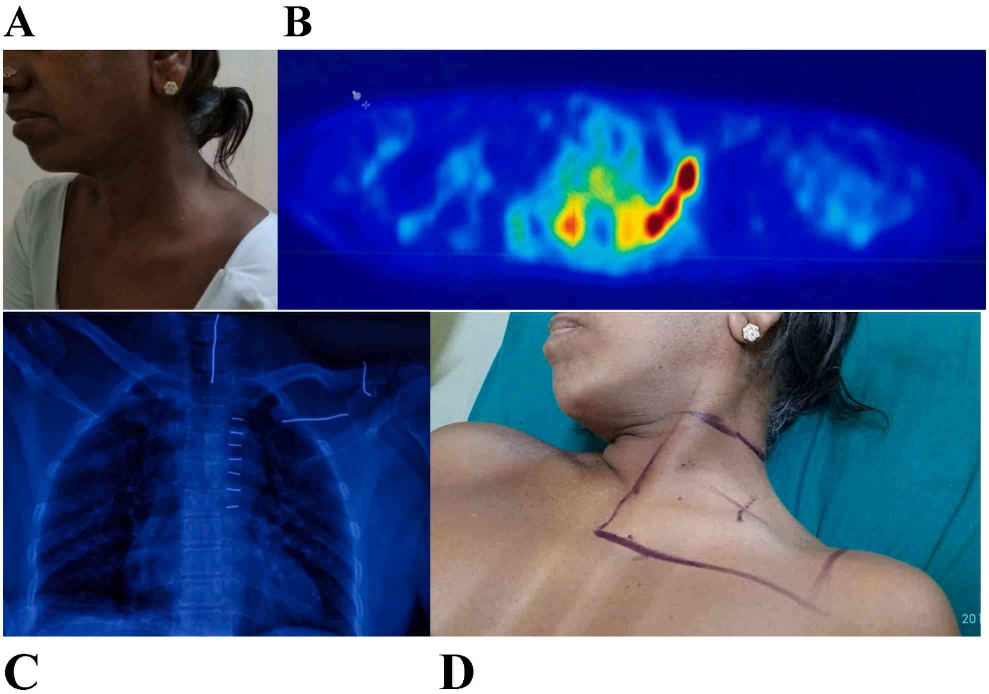

Fig. 3. Conventional radiotherapy planning (delineation of portal) for supra-clavicular irradiation. (A) Fullness and bulge of left supra-clavicular fossa can be noted. (B) PET image of FDG avid left supra-clavicular lymph nodes. (C) Borders of preliminary radiotherapy portal for supra-clavicular irradiation in supine position. (D) Supine x-ray of supra-clavicular region obtained after placing customized scale in x-ray FOV and soldering lead wire over border of preliminary supra-clavicular radiotherapy portal (order of picture is clock-wise).

most extent was needed to delineate superior/upper and inferior/lower border of this portal (Figs. 4 and 5).

2.8. Spinal portal

External occipital protuberance, first palpable spinous process at the base of neck and highest point of iliac crest corresponded to C1, C7 and L4 vertebrae respectively. Vertebrae were counted downwards or upwards from C7 or L4 respectively with patient in prone position. Height of each vertebrae is measured to be 3 cms in our patient population. Hence, pair of points are marked 4.5–5 cm above and below the tip of spinous process of the vertebrae bearing metastasis. A horizontal line at these points will be upper and lower border of the portal. Another pair of points is marked on either side of midline of body at a distance of 2.5–3 cms. Vertical lines passing through this pair of points and joining upper and lower border completes the preliminary portal for spinal irradiation. Floating rib (posterior end corresponded to 12th vertebrae), L4-5 junction, intervertebral disc space were the important x-ray bony landmarks with respect to delineating final radiation portal. Additionally, lytic/sclerotic bony changes on x-ray determined final portal. Patients with poor performance status can be planned in supine position with portals marked on anterior abdominal wall. Radiotherapy collimator is adjusted to the borders of this radiation portal followed by lifting the couch to the level of horizontal laser (making SSD of 80 cms for PA portal) and treatment of spine from posterior aspect of body after rotating the gantry by 180° (Fig. 6).

2.9. Preparations before obtaining x-ray to delineate radiotherapy portals

A customized scale is prepared by sticking longitudinal half of 3M Transpore Plastic Hypoallergenic Adhesive Tape (St. Paul, MN, USA) over conventional centimetre scale. 6-7 bits of soldering lead wire is placed on sticky side of transpore each at an interval of 1 cm. So prepared customized scale is unstuck from the conventional centimetre scale (Figs. 7 and 8).

Once the preliminary radiotherapy portal is marked over the skin surface, soldering lead wire is placed over each of the borders of said portals and secured with the help of transpore. Customized scale is again stuck to the skin surface within field of view (FOV) of x-ray taking into consideration the amount of respiratory excursion of the structure and body curvature. Customized scale is stuck within the FOV of x-ray where the respiratory excursion and body surface curvature is minimal after attaining maximal relaxation of patient (Figs. 2 and 4).

Collimator of diagnostic x-ray is placed at 80 cms from the skin surface bearing preliminary radiation portal by using plumber's metal measuring tape. Borders of preliminary radiation portals are moved in x-, y- and z-axes based on measurement obtained from markings/shadows of customized scale on x-ray film to finalize the radiation portals (Fig. 4). Check x-ray after finalization of portals may be obtained to verify the accuracy of markings. All the lead markers were either discarded or sterilized with alcohol based disinfectant after finalization of radiotherapy portals.

2.10. Measurement of body separation

It was achieved using body caliper.

3. Results

3.1. Patient selection for conventional technique

Radical pelvic irradiation of patients (of carcinoma cervix without pelvic lymph node) with body (pelvic) separation of up to 21–22 cms and most of the patients needing palliative radiotherapy were planned and treated by conventional technique.

3.2. Intent of treatment

Presence or absence of pelvic lymph node determined the extent of irradiation. Whole pelvis with or without para-aortic lymph nodal area was irradiated with radical intent for disease confined to pelvis with metastatic lymph nodes on diagnostic computed tomography (CT) scan. Intent of irradiation was palliative in the presence of conglomerate/multiple discrete para-aortic lymph node. Irradiation of para-aortic area along with pelvis by conventional radiotherapy portal was done mostly with the palliative intent in this subset of patients. Spinal, mediastinal, supraclavicular and whole/partial brain irradiation were performed with palliative intent for alleviation of symptoms of metastasis. Patients

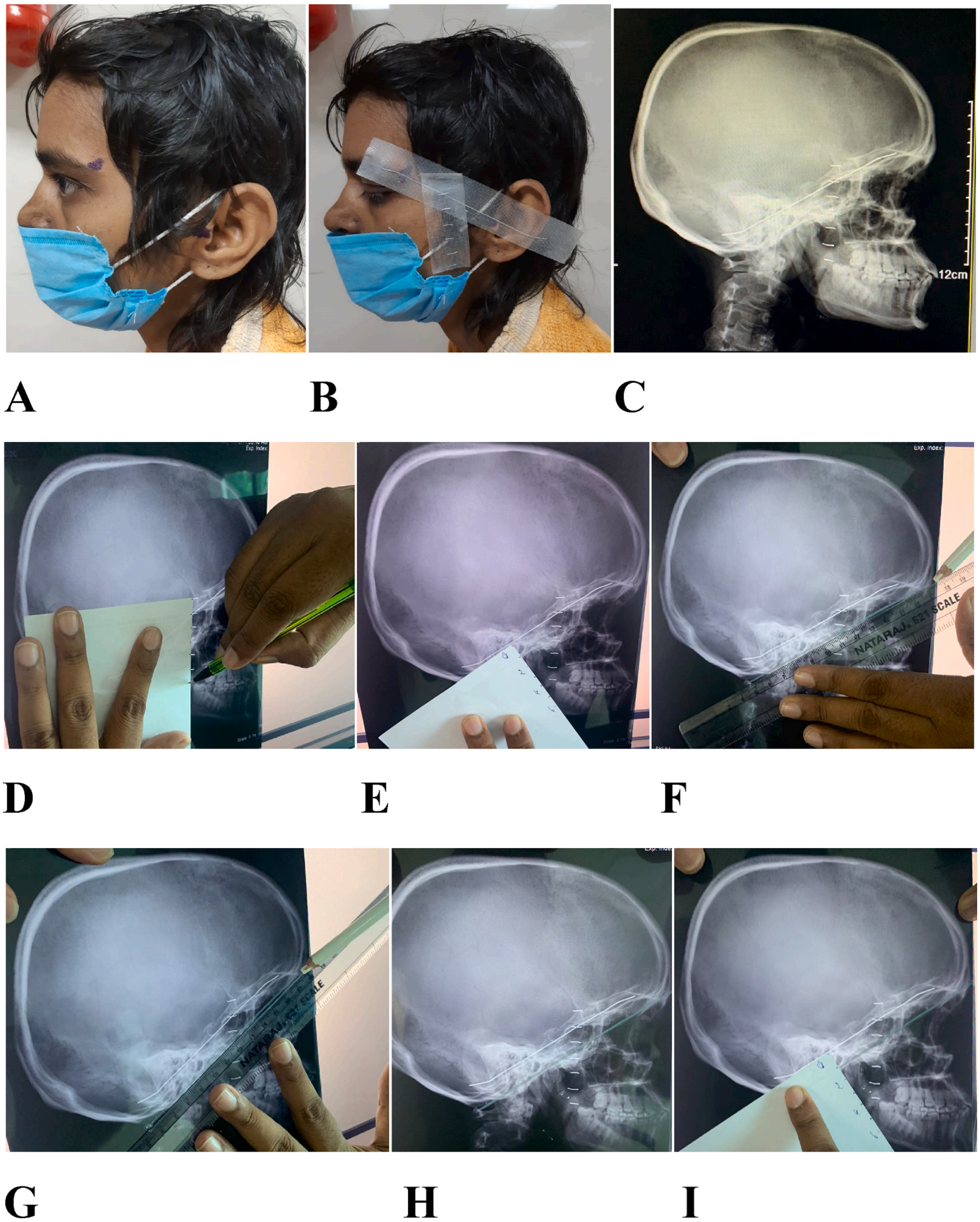

Fig. 4. Illustration of planning process of conventional cranial radiotherapy portal for gynaecologic oncology patient presenting with brain metastasis. (A) Two points are marked over lateral face (one over lateral end of supra-ciliary arch, second at the root of tragus of ear). (B) Soldering lead wire stuck along middle of adhesive side of tape is placed over lateral face so that the wire passes over both these points. An imaginary line transvering these points is the preliminary inferior border of lateral skull radiotherapy portal. Superior, anterior and posterior borders of conventional radiotherapy portals are kept in air beyond the outer table of vault. Customized scale is stuck to skin of lateral face to account for magnification and will act as guide/reference to adjust the lower border of portal in terms of centimeters. (C) Left lateral skull x-ray was taken after sticking soldering lead wire and customized scale to skin surface. (D) Translating the centimeter scale on x-ray image, shadow of which is generated by customized scale place over skin surface, to a piece of plain paper. Now translated centimeter scale on the paper will be used to move the lower border of conventional radiotherapy portal in +y or –y axes depending on the shadow of linear soldering wire placed over the same border of said portal. (E) Translated paper scale requires the movement of lower border of this portal by 1 cm in –y direction. (F & G) Glass marking pencil[¥] is used to remark the lower border of conventional lateral skull portal on x-ray film in order to take this border to the corrected new position. i.e. 1 cm lower than the shadow of linear soldering wire along its entire length. (H) Corrected position of lower border of lateral skull portal is marked in white by glass marking pencil. I. Re-measuring the distance between shadow of linear lead wire and the parallel line drawn 1 cm inferior to this line in order to completely cover the whole brain target with the help of translated paper scale. The next part of procedure is moving the lower border on the skin surface of lateral face of patient in inferior direction by 1 cm and this will be the corrected positon of lower border of conventional lateral skull radiotherapy portal[Φ] ¥ Advantage of glass marking pencil is that its marking can be erased by guage piece soaked in alcohol. Φ Lower border of collimator of Co-60 teletherapy equiment is placed 1 cm below and parallel to corrected lower border of conventional radiotherapy portal and this will be the angle of collimation for all the future fractionated treatment.

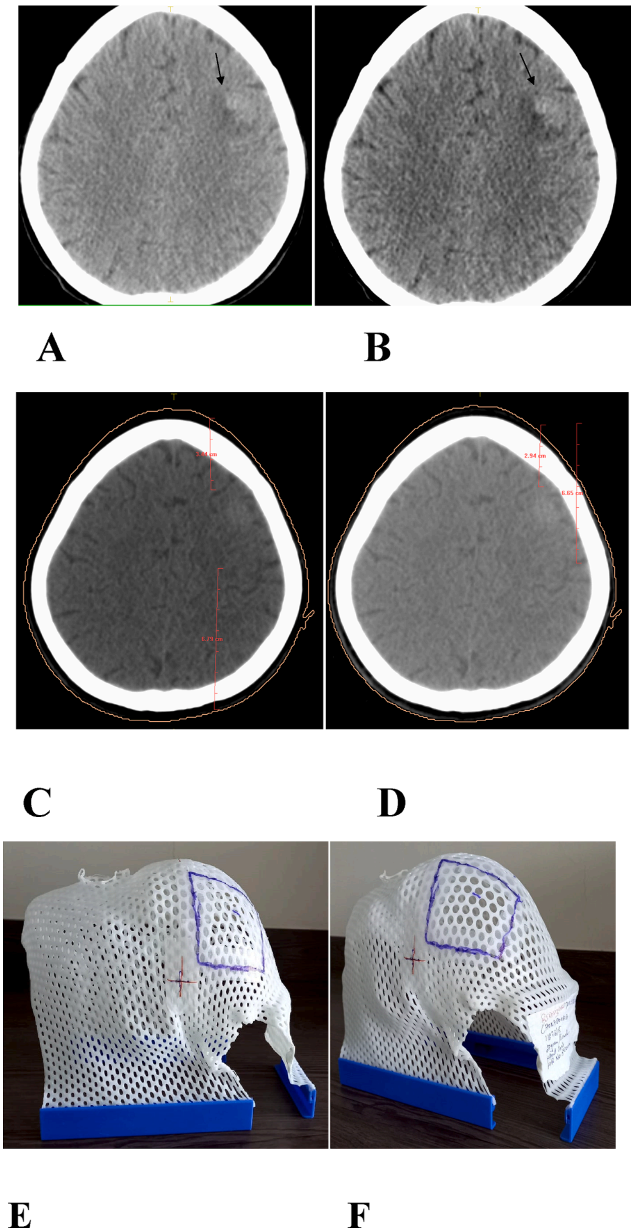

Fig. 5. Illustration of process of delineation of conventional radiotherapy portals for partial brain irradiation in cases of single metastasis of brain. (A & B) Single brain metastasis in left frontal lobe with solid and cystic component (shown in black arrow). (C) Measurement of distance between outer table of frontal bone and anterior-most extent of metastasis, that between outer table of occipital bone and posterior most extent of tumour. (D) Measurement of distance between outer table of frontal bone and anterior-most and posterior-most extent of brain metastasis. (C & D) is helpful to delineate anterior and posterior border of radiation portal (in supine position) of partial brain irradiation. Superior and inferior border of the said portal will be delineated by measuring the distance between upper-most and lower-most extent of metastasis from outer table of the skull vault. The final result is delineation of conventional lateral partial brain portal shown in figure (E & F). While delineating lateral skull radiotherapy portal, attention should be given to exclude critical normal tissue like eyes, brainstem from the portals.

presenting with uremia also received palliative pelvic irradiation in contrast to those presenting with only azotaemia.

3.3. Portals of irradiation

Anterio-posterior/Posterio-anterior (AP/PA) portals were used for pelvic, para-aortic and mediastinal irradiation. Right and left lateral portal were employed for whole/partial brain radiation therapy. AP and PA portals were utilized for supra-clavicular fossa and spinal irradiation respectively.

3.4. Delivery of radiation

Radiotherapy to area of interest was delivered through the portals designed by aforementioned methods using either Cobalt-60(Co-60) teletherapy equipment (Theratron 780C, E1, E2) or Varian low/high energy non-MLC linear accelerator (SSD was kept at 80 cms and 100 cms respectively)

3.5. Dose and fractionation

Whole pelvic dose of 50.4 Gy/28 fractions @ 1.8 Gy/fraction over 5½ – 6 weeks followed by brachytherapy to dose of LDR equivalent of 30 Gy. Various dose fractionation schedules were utilized for palliative management of patients: 40 Gy/15 fractions over 3 week was the schedule used for patients with good performance status with recurrent solitary bone metastasis after one or two years of radical therapy. 30 Gy/10 fractions over 2 weeks, 20 Gy/5 fractions over a week and 8 Gy/1 fraction were the other palliative dose fractionation regimes, patients received in our clinic.

3.6. Position of patient

The entire process from preliminary marking to finalization of radiotherapy portal and delivery of radiotherapy (except for spinal conventional radiotherapy planning and irradiation) was carried-out only in supine position.

In conclusion, delineating of conventional radiotherapy portals by the above technique and delivery of radiotherapy through these portals was feasible in selected patients of carcinoma cervix.

4. Discussion

Following were the factors behind our decision to treat selected patients of carcinoma cervix through standard AP/PA pelvic portal using the aforementioned technique in the present study. Dosimetric studies have demonstrated that CTV was better covered by 3D-CRT than with conventional technique (Bednaruk-Młyński et al., 2003, 2008). Nevertheless, clinical outcome of 2-D radiotherapy technique was statistically non-inferiority and the clinical implementation was simpler as compared to that of 3D-CRT. Therefore, large majority of patients of carcinoma cervix across the world are still being treated by 2-D conventional technique (Thakur et al., 2013). Although four-field box technique has demonstrated advantage of better rectal sparing in multiple studies as compared to standard AP/PA portal, it also carries inherent risk of missing the target in young patients, pre-menopausal women, those with bulky cervical disease, retro-/anteverted uterus (Nagar et al., 2004; Kim et al., 1994). Surface anatomy alone based-planning has its own limitation in terms of adequately covering target due to variation of anatomy and pattern of growth and spread of tumour (Rai et al., 2014).

Yu Lin et al. and Wujanto have reported the incidence of positive pelvic lymph nodes at around 35% and 50% in stage II B and IIIB cervical cancer respectively (Wang and Wei, 2015; Wujanto et al., 2019) Patients with positive pelvic lymph node were treated by extended field radiotherapy (EFRT) as a protocol in our study. Lean patients requiring radical pelvic radiotherapy alone, palliative extended field-, mediastinal-, supraclavicular-, spinal- and whole/partial brain radiotherapy was planned and treated by delineation of portals by aforementioned technique. Table 1 illustrates the rationale for choosing the surface anatomic landmark and measurement of preliminary radiotherapy portal.

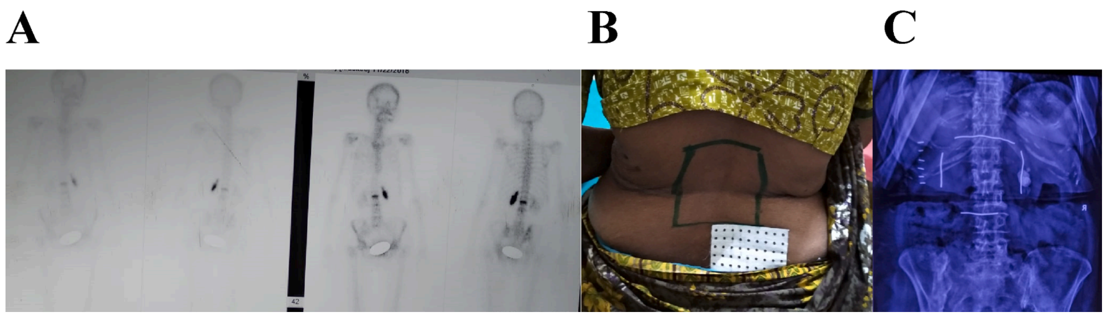

Fig. 6. Conventional radiotherapy planning (delineation of portal) for spinal irradiation. (A) Bone scan shows solitary vertebral body metastasis. (B) Preliminary skin marking of spinal fields on lumbar region C. Supine PA x-ray of lumbar region obtained after placing customized scale in x-ray FOV and soldering lead wire over border of preliminary spinal radiotherapy portal.

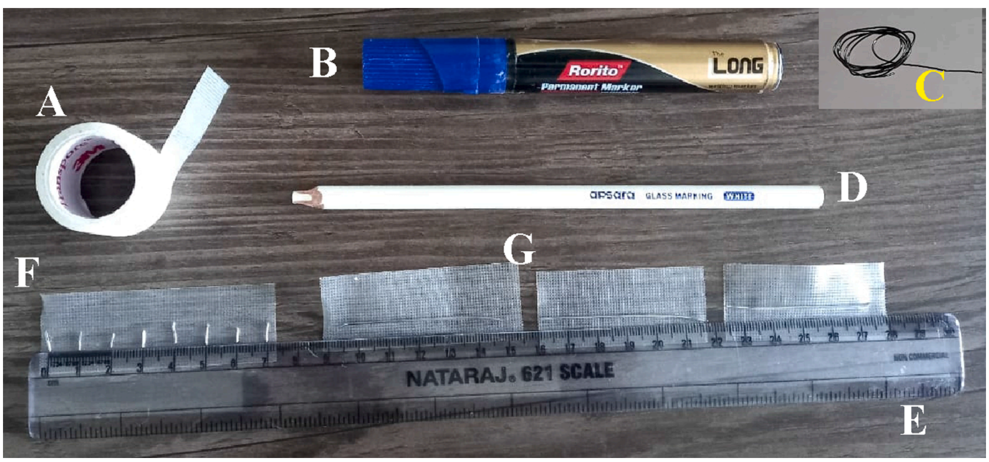

Fig. 7. Figure depicts items needed for delineation of conventional radiotherapy portal: (A) 3M Transpore plastic surgical tape of 1½ inch. Longitudinal half of adhesive side of this tape was stuck to plastic centimeter scale and bits of soldering lead wire placed at an interval of 1 cm over the other longitudinal half of adhesive side of this tape. (B) Permanent skin marker to make a preliminary skin marking. (C) Soldering lead wire: bits of this wire were used to prepare customized centimeter scale. Certain length of this wire will be stuck along middle of the adhesive side of transpore surgical tape to be placed over preliminary borders of radiation portals. (D) Glass marking pencil was helpful to define final border of radiotherapy portal on x-ray film. (E) Transparent virgin plastic centimeter scale was used to prepare customized centimeter scale. (F) Customized centimeter scale prepare using 3M Transpore plastic surgical tape and was stuck to body surface adjacent to area of interest (Adhesive side is displayed). (G) Soldering lead wire is stuck along middle of adhesive side of transpore surgical tape and was stuck over the preliminary borders of radiotherapy portals.

Obese patients requiring radical radiotherapy, all the patients with indications for radical EFRT were treated by either 3-D conformal radiotherapy (3-D CRT)//Intensity Modulated Radiotherapy (IMRT). Obese patients treated under Co-60 teletherapy equipment by standard AP/PA portal had increased morbidity and mortality due to perineal, pelvic and haematological reactions. Obese patients and patients with pelvic lymph nodes were planned and treated by 3-D CRT with radical intent lest the morbid and life-threatening toxicity of perineal skin reactions and under-coverage of target/inadvertent irradiation of kidneys respectively (Kumar and Bhasker, 2020)

FOV of diagnostic x-ray was guided by the borders of preliminary radiotherapy portal marked by permanent skin marker on skin surface of corresponding site and anatomical orientation (.i.e. anterior aspect, posterior aspect, right/left side of the body). Internal anatomy of the site of irradiation was considered along with the bony and soft tissue anatomical landmarks to delineate the borders of preliminary radiotherapy portal (Table 2).

Customized scale was introduce to account for magnification factor of diagnostic x-ray and helped to delineate portals by guiding movement of border of preliminary portal in x-, y- and z-axes. The entire process of planning (except that of spinal – prone position is preferable for this site) happened in supine position. Un-predictable gravitational sag of body wall and viscera that may lead to geometric miss of the target is minimal in supine position thereby optimizing validity and reliability of radiation portals (Fig. 2).

Radiation oncologists have to exercise caution at this point of planning as there are possibilities of error in delineation of portals. Any mismatch of the intended border anticipated based on surface anatomy landmark with that derived after the above-mentioned procedure has to be sought and due vigilance has to be exercised during the whole process (Figs. 2 and 4). In cases of doubt, repeating the process of planning from the start may reduce any sort of error that would have crept in during the planning process. Reasons for such mis-match are hurried respiration, anxiety, rotation, non-cooperative patient and obesity among others.

The present manuscript has detailed the technique of conventional radiotherapy planning by utilizing soldering wire and diagnostic x-ray equipment without presenting any outcome data (local control and toxicity) pertinent to this particular technique. Concern was raised regarding effectiveness of this technique for conventional radiotherapy planning and delivery without outlining the actual outcome data. However, a brief description of milieu in developing countries with respect to delivery of radiotherapy in real-world setting would be helpful to understand the need for planning and delivery of radiotherapy by this very technique: Number of patients with proven cancer

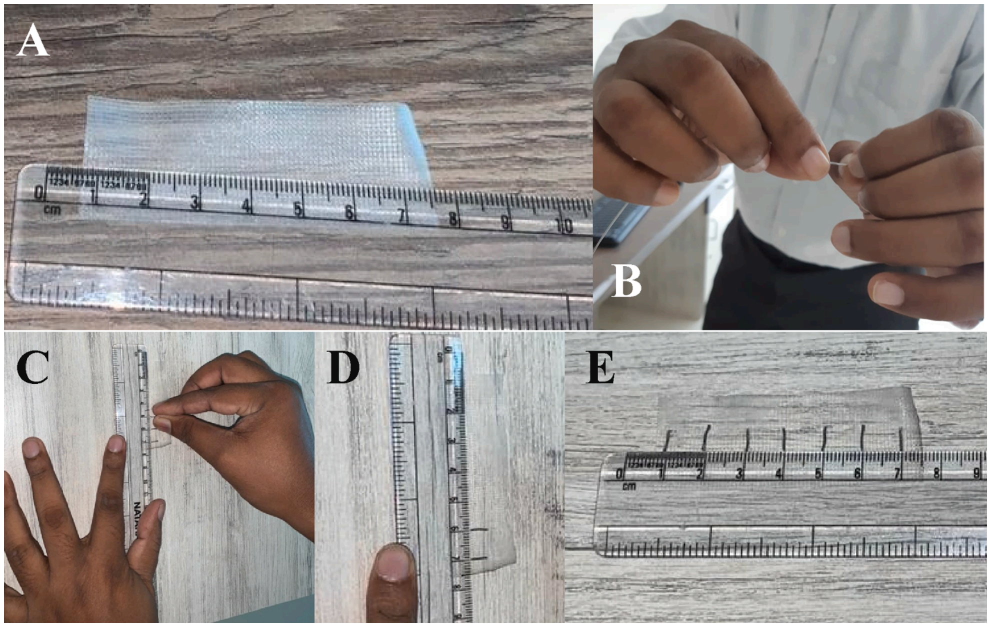

Fig. 8. Step-by-step description of procedure of preparation of customized centimeter scale; (A) Sticking of longitudinal half of adhesive side of 3M transpore surgical tape over the posterior side of virgin plastic centimeter scale along the centimeter reading. (B, C, D) Breaking of soldering wires into bits in order to stick them on adhesive side of tape at an interval of 1 cm using plastic centimeter scale as a reference. (E) Completion of preparation of customized centimeter scale.

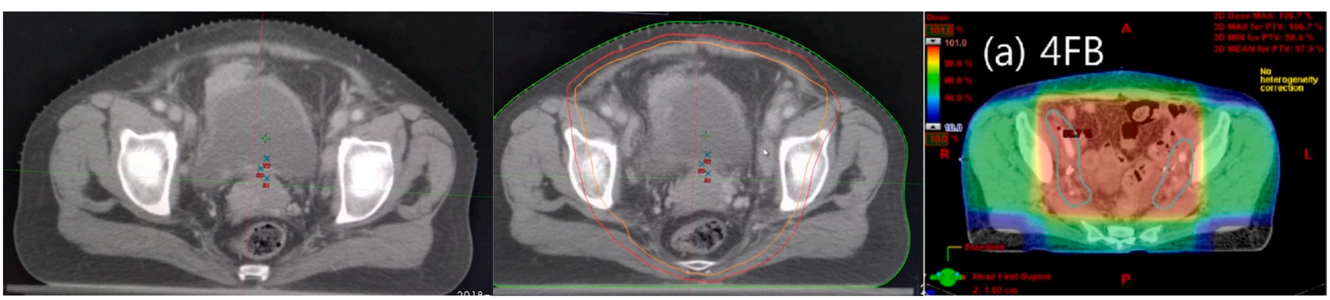

Fig. 9. Figure depicting justification of practice of conventional radiotherapy in selected cases. (A) Axial computed tomography (CT) image of patient of carcinoma cervix with deposit on right anterior wall of bladder. (B) Clinical Target Volume (CTV) and Planning Target Volume (PTV) delineated on planning CT image covers entire pelvic cavity. (C) Dosimetry of four-field box technique reveals that the whole pelvis is receiving mean dose of 97.9% of prescribed dose. [Reproduced with permission from Elsevier. Article of Sung et al. (2016) published in Physica Medica] (Sung et al., 2016).

registered in our centre is around 9000/year (Hospital Based Cancer Registry Department of Epidemiology and Biostatistics (DEB), 2020). Nearly 60% of all patients with cancer, at some point during course of treatment, need radiotherapy as per International Atomic Energy Agency (IAEA) .i.e. around 5500 patients/year should report to radiotherapy (IAEA, 2010). However, only around 3000 patients reported for first fraction of radiotherapy in our institute. Around 10% of all patients on radiotherarpy have unplanned/unintended treatment interruption. Literature has reported that around 20% of patients default radiotherapy in real-world setting (Roick et al., 2018; Pujari et al., 2017). In our institution, this figure is much higher .i.e. 40% of patients default radiotherapy. [Personal communication – Dr. V. Lokesh, HOD, Radiation Oncology, Kidwai Memorial Institute of Oncology]. This rate rises further to 70% in cases of peripheral cancer centre (Kumar and Bhasker, 2016). Only around 30% of patients after completion of therapy attend follow-up due to varied reasons despite impressing upon patients the importance of such visits (Uma Devi, 2009). Mostly patients returning for follow-up either have some symptoms of recurrence or adverse events of anti-cancer therapy (Baiocchi et al., 2014). Similarly, in real-world set-up, studies have also demonstrated the cost-effectiveness of follow-up scheduled based on case-to-case basis rather than uniform and generalized schedule (Boysen et al., 2016). Hence, objective assessment of oncological outcome is bit difficult in this situation and the results may grossly be biased (Swaminathan et al., 2008).

Then the question arises as to what is the method to ascertain the effectiveness of therapy and know about adverse events of anti-cancer therapy in such set-up. At this point, we have to return back to our clinic to answer this question especially from the point of view of resource-constrained set-up. Consecutive two obese patients (anterio-posterior body separation of >21–22 cms) – planned by conventional technique and treated under Co-60 teletherapy unit – had Common Terminology Criteria for Adverse Events Reporting (CTCAE v4.0) grade III perineal skin adverse events and these two patients died of complication of adverse events (Kumar and Bhasker, 2020). One emaciated patient of carcinoma cervix with medical history of retroviral disease on radiotherapy, fitting the definition of AIDS, developing similar CTCAE v4.0 grade III reaction also died of complication. From that point of time, all the obese patients presenting with carcinoma cervix were planned by 3-D Conformal Fadiotherapy (3-D CRT) with high energy beams (usually 18X rather than 6X). Therefore, obese patients were treated by 3-D CRT and non-obese patients by conventional technique using soldering wire under Co-60 teletherapy unit as a matter of treatment policy.

Observed frequency of returning of patients with distressing

Table 1

Rationale for delineation of borders of preliminary radiotherapy portals for planning of radiotherapy in management of carcinoma cervix.

Portal	Border	Anatomical consideration	Point/s on body for preliminary marking
Pelvis	Lower	Whole of vagina is considered in clinical target volume (CTV) for intact cervix (Bansal et al., 2013)	Just beyond the vaginal introitus over upper thigh
	Upper	Highest point of iliac crest corresponds to L4 vertebrae (Chakraverty et al., 2007)	Line projecting across anterior abdominal wall from highest point on iliac crest on one side to same point on contralateral side. Upper border of pelvic portal is placed at intervertebral disc of L4-L5 vertebrae.
	Lateral	Maximum width of pelvic brim is around 13.5 cms (Drake et al., 2005)	Adding margin of 1 – 1.5 cms on either side of pelvic brim will make width of this field around 16 cms
Para-aortic	Lower	Lymph nodes around abdominal aorta and inferior vena cava upto its division as common iliac vessel at the level varying from L3 to L5 (Rai et al., 2014)	Gap between lower para-aortic and upper pelvic border has to be 0.5 cm in order to avoid hot-spot. Problem with the junction shift is the reason for limiting use of this portal for palliative para-aortic irradiation alone.
	Upper	Xiphisternum and umbilicus are at the level of T10 and L3 vertebrae respectively. Mid-point between the above structure roughly corresponds to T12-L1 junction (Drake et al., 2005; Panici et al., 1992)	T12-L1 junction is upper border of this field
	Lateral	Mean distance between the lateral extent of vertebral body and kidney is 2–3.5 cms. Width of lumbar vertebrae is around 5 cms (Iwanaga et al., 2018)	This is the justification for keeping 8 cms as the width of preliminary portal
Mediastinum	Lower	Superior mediastinum extends from thoracic inlet to imaginary line passing from lower border of anterior end of left 2nd rib to superior border of posterior end of right 3rd rib. Anterior end of 2nd rib is attached to manubrio-sternal angle (angle of louis)	Rib immediately lateral to angle of louis is 2nd rib on either side of midline of body. Identifying lower border of anterior end of 2nd rib on either side and joining these border across the midline of body
	Upper	Upper border of medial end of clavicle is helpful	Horizontal line joining these points
	Lateral	Mean of maximum width of mediastinum is 8 cms in supine position (Lai et al., 2012)	Marking a point at 5 cms on either side of midline passing though manubrium sterni. Then drawing a vertical line passing through these points that joins upper and lower border on either side.
Supra-clavicular	Lower	Arch of subclavian artery forms lower extent of supra-clavicular fossa. Subclavian artery arches over superior surface of 1st rib.	Line passing across ipsilateral intercostal space between 1st and 2nd rib
	Upper	Omo-hyoid muscle divides posterior neck into level 5A and level 5B. Intermediate tendon of omohyoid is located at the level of arch of cricoid	Upper border of cricoid cartilage can be marked as upper border of this portal
	Lateral	Junction of medial 2/3rd and lateral 1/3rd of clavicle	A vertical line passing across this point is the lateral border
	Medial	Origin of sternal head of sternocleidomastoid muscle to be palpated to midpoint of upper border of manubrium sterni	A vertical line passing through the mid-point of upper border of manubrium sterni is the medial border
Whole brain	Lower	Identifying supra-ciliary arch by palpation over eyebrow. Trace this arch to its lateral end A point over junction of tragus with face	A point joining lateral end of supra-ciliary arc to tragus of ear
	Superior	Vertex of skull has outer and inner table.	Vertical line over scalp of forehead at the level of pupil with eyes looking straight ahead.
	Inferior		Fall-off in the air beyond outer table of parietal and occipital bone
	Upper		Fall-off in the air beyond outer table of frontal and parietal bone
Spinal	Lateral	Width of vertebral body varies between ~2.5 and 5.5 cms for cervical to lumbar vertebrae respectively (Busscher et al., 2010)	Marking a point at 3 cms from midline/tip of spinous process of vertebrae on either side of midline.
	Upper and lower	Spinous process of thoracic/dorsal vertebrae is inclined downwards. The tip of spinous process corresponds to the next lower vertebral body. Otherwise, tip of spinous process is at the level of corresponding vertebrae. Highest point on iliac crest if projected over loin passes through tip of L4. First palpable spinous process at the base of neck corresponds to C7 vertebrae. Inferior angle of scapula with hands in neutral position corresponds to D8/spinous process of D7 vertebrae	As a general principle, radiation portal for spinal irradiation includes one vertebrae each above and below the diseased vertebrae/a. Counting the tip of spinous process with patient in prone position to determine the upper and lower border. Marking a horizontal line immediately above the corresponding spinous process will be preliminary upper border. This is followed by joining the right and left end points of said upper border to upper ends of right and left lateral borders respectively completes upper border. Similarly, marking a horizontal line immediately below the corresponding spinous process will be preliminary lower border and is followed by joining right and

(continued on next page)

Table 1 (*continued*)

Portal	Border	Anatomical consideration	Point/s on body for preliminary marking
			left end points of said lower border to lower ends of right and left lateral borders complete the portal.

Table 2
Rational for delineation of radiotherapy portals on skin surface of particular anatomical region and orientation of body.

Orientation	Sites/Anatomical region	Rationale
AP/PA	Pelvis	Four field box technique delivered 97.9% of prescribed dose to whole of pelvis in the study published by Sung et al. (2016). Both standard 2-field AP/PA and 4-field box technique are equivalent in terms of target coverage and the latter is better than former in terms of sparing rectum (Fig. 9). However, multiple studies have demonstrated the weakness of conventional 4-field box technique with respect to target coverage especially by lateral pelvic portal (Bednaruk-Młyński et al., 2003; Kim et al., 1994)
	Para-aortic lymph nodal area	Kidneys on either side of para-aortic lymph nodal area (right L1-3 and left T12-L2 in supine position) precludes use of lateral portals. Para-aortic area is near the centre of transverse axis of abdomen (Iwanaga et al., 2018; Busscher et al., 2010). Hence, the standard AP/PA portal is suitable to irradiate this area.
	Superior mediastinum	Unnecessary irradiation of shoulders and lungs by lateral fields preclude its use in irradiation of this area.
PA	Spine (in prone position)	Easy to count spinal level, mark preliminary radiotherapy portal and finalize the same. Anterior-most extent of spine/anterior surface of vertebal body was around 6–7 cms in most of patients. Hence, PA field was both convenient as well as helped to achieve normal tissue sparing.
RL/LL	Skull	These fields are easy to plan, comfortable to patients and no critical structure are present in the path of radiation.

symptoms along with residual/recurrent on clinical pelvic examination was considered as surrogate for tumour control. Patients of carcinoma cervix treated by whole pelvic radiation dose of 45 Gy/25 # over 5½ weeks returned more frequently with residual/recurrent disease within first six months of completion of radiation therapy [that included 7 Gy/3 fractions of intra-cavitary brachytherapy (ICBT)]. Hence, whole pelvic dose was increase to 50.4 Gy/28 # as was practiced in some of international centres (Wang et al., 2017). This scheme of dose escalation was associated with non-returning of patients with recurrent disease within first six months of therapy. However, occasion patients returning with grade III proctitis were sucessfully managed by medical line of treatment in most instances. External beam radiotherapy dose intensification was followed by brachytherapy intensification by application of interstitial brachytherapy (ISBT of 7 Gy/3 fractions) instead of ICBT. Patient receiving ISBT returned back with distressing perineal symptoms that were not associated with recurrence. Therefore, the schema of management of carcinoma cervix in non-obese patients was external beam radiotherapy (50.4 Gy/28 Fr) by conventional technique under Co-60 teletherapy unit followed by ICBT (7 Gy/3 Fr) and ISBT reserved for only those patients with destroyed cervix or abnormal vaginal anatomy. Most patients did not come back with any pelvis signs/distressing symptoms with this schema except for occasional patients returning with recurrence and/or grade III proctitis (most resolved with medical measures).

Concerns were again raised regarding unnecessary irradiation of normal tissue thereby causing morbid perineal reaction by placing inferior border of conventional pelvic radiotherapy portal beyond introitus to include entire vagina. Conventional textbook description is placement of lower border of pelvic portal around 2 cms inferior to lower vaginal extent of cervical cancer. Placing guage piece soaked in barium sulphate solution at the lowest point of vaginal disease was used as reference to delineate lower border of conventional pelvic radiotherapy portal. This is true in case of obese patients with deep vagina where significant lenght of vagina can be spared out of radiation portal. However, in case of non-obese patients, distance between lowest vaginal extent of cervical tumour and the introitus was between 1 and 3 cms in consecutive patients presenting to radiotherapy out-patients. Literature published by PGIMER (premier institute functioning in the same geographical area under the similar demographic and clinical circumstances as our institute) also recommends to include entire length of vagina in CTV (Bansal et al., 2013). It is also true that placing inferior aspect of pelvic field inferior to the introitus increases the rate of perineal reaction. Nevertheless, most of the perineal reactions were ≤CTCAE grade 2 and resolved by application of gentian violet paint. These reactions also did not delay the brachytherapy as most of the reactions resolved during the course of clinical diagnostic work-up and pre-anesthesia check-up (PAC) for brachytherapy.

5. Conclusion

To conclude, radiotherapy planning of selected patients of carcinoma cervix is feasible utilizing locally available resources (soldering wire, transpore, diagnostic x-ray equipment, plumber's metal measuring tape). Such technique may be in-expensive, simple, less demanding on time, resources and expertise. Hence, future studies will be planned to validate this technique.

Author contribution

Ramaiah Vinay Kumar has contributed to conceptualizing the study, collection of data, analysis of data and writing the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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