Recent Technological Advancements in Respiratory Gating Devices

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Abstract
Background: The occurrence of motion in the thoracoabdominal region during radiotherapy treatment is an inherent challenge affecting the accuracy of the radiation beam. To address this challenge, a margin is often incorporated to compensate for the motion, but it has been reported to have several limitations. Consequently, respiratory gating has emerged as an integrated feature within radiotherapy-related machines. This innovative approach is designed to overcome motion-related challenges, leading to a reduction in the required margin and an improvement in the accuracy of the radiation beam.

Methods: This study reviews the literature published in English between 2012 to 2021 regarding breathing monitoring devices used in the clinical or research stage. Furthermore, articles published before 2000 were traced to strengthen the theories.

Results: Several monitoring devices had been reported to have respiratory gating purposes, but some were not equipped for this function. Furthermore, these devices were often developed using non-contact equipment, such as lasers and cameras, to provide accurate and precise measurements. One of their key advantages is the lack of physical attachment to the patients, thereby preserving comfort. The development of respiratory gating devices had significant potential to enhance the quality of radiotherapy treatment. This was manifested through more effective tumor and organ treatment and reduced toxicity. These benefits had the potential to extend the life expectancy of patients with respiratory-related cancer.

Conclusions: Based on the results, respiratory gating was an advantageous technique in radiotherapy treatment. The development of respiratory gating devices enhanced patient comfort and the effectiveness of treatment.

Introduction
Respiratory gating is an essential technique used in radiotherapy to enhance the accuracy of tumor localization within the thoracoabdominal region. Furthermore, this region comprises critical organs, such as the lungs, breasts, and liver, where the motion induced by the respiratory system can impact treatment precision. The motion primarily manifests as changes in the surface of the chest due to breathing. During inhalations, the chest surfaces ascend but descend during exhalation. This respiratory movement can lead to geographical errors and toxicity in organs at risk (OARs), underscoring the importance of respiratory gating during treatment. The implementation of this method has been reported to have the ability to increase the accuracy of the radiation beam and decrease the risk of toxicity in healthy organs, thereby improving the treatment outcome [1–3]. A variety of devices are available for this purpose, each with its unique principles but a common objective. In clinical settings, these devices often come at a high price, leading to the development of cost-effective alternatives with comparable outcomes. This study provides a brief overview and developmental history of respiratory gating devices used clinically along with Linear Accelerator (Linac) to treat cancer patients.

According to the International Commission on Radiation Units and Measurements (ICRU) 50 and 62 [4,5], the management of tumor motion must be considered when treating cancer patients. To address this, a common approach comprises the addition of a margin around the target volume. However, it is essential...
to recognize the limitations of this method. In cases of significant motion, the inclusion of a margin can inadvertently expose healthy tissue to radiation. Another strategy to effectively compensate for tumor motion during treatment is the implementation of respiratory gating in radiotherapy. This technique yields substantial benefits, primarily in terms of geometric precision and dosimetric improvements [6]. Furthermore, respiratory gating serves to minimize uncertainties arising from the effects of breathing motion during treatment.

Respiratory gating has been proven to be invaluable in mitigating the impact of organ motion caused by respiration in chest-related cancer radiotherapy, such as breast cancer [2,7]. In breast cancer radiotherapy, the application of this technique can reduce doses to OARs, such as the lungs, heart, left anterior descending artery, and other organs. Although the separation between the breast and heart varies between patients, some patients cannot fully benefit from its advantages, leading to increased equipment and operational costs [1,8].

The technique operates on the principle of measuring external motion from breathing activity based on the assumption that it corresponds with the internal tumor motion. Furthermore, a model that can correlate the external and internal motion must be used [9]. Accurately tracking breathing movement is essential because the radiation beam must be delivered precisely and accurately to ensure the delivery of optimal doses. This tracking procedure must also be implemented in a contactless manner to prevent disturbance to the beam and make patients, especially the elderly, more comfortable with the setup [10].

The consideration of time delay is also imperative in the context of respiratory gating. A time delay refers to the interval between the moment when the tumor or its surrogate enters the gated region and the subsequent initiation of the radiation beam, and vice versa. The American Association of Physicists in Medicine (AAPM) Task Group 142 states that when the target speed is 2 cm/s or less, the interval must not exceed 100 ms [11]. Broad time delays can lead to treatment inefficiencies and geographical errors. Therefore, the parameter is a crucial indicator in determining the delivery accuracy. Each Linac must also measure the parameter when a new gating device is applied [12,13].

While some degree of time delay is expected, it must adhere to the protocols in AAPM Task Group 142. A time delay is often caused due to the linear accelerator’s response time to the signal given by the gating device. Several studies have shown that the implementation of algorithms capable of predicting and anticipating the respiratory motion signal can reduce the time delay parameter. After integration, these algorithms are often loaded into the software of the gating device system [13]. Therefore, this study aims to provide a comprehensive overview of the development and use of respiratory gating devices in research and clinical settings. The evolution of these devices from their inception to the current state, as well as their roles, was explored. Other key aspects, such as the working principle of the respiratory gating device, existing implementation, and current development were studied. The results of this study are expected to facilitate the advancement of respiratory gating devices for enhanced patient care.

METHODS

This review focused on the use of respiratory gating devices and their mechanism of action in clinical settings. Google Scholar Search Engine, Pubmed, and IEEE Xplore were to search for the relevant articles. Furthermore, the inclusion criteria were articles published in English between 2012 and 2021 with the keywords “respiratory” or “breathing” plus “monitoring” or “tracking”. The review included papers with devices that worked in a real-time tracking algorithm. Articles that tracked the recorded video or the “non-real-time” tracking algorithm were excluded. The keyword “respiratory gating” was also included to obtain more information about the topic. From the search results, the topic was traced back to papers published before 2000 to strengthen the theories.

Physicians had used several devices for respiratory gating. This review examined studies that developed and/or clinically tested respiratory gating devices. These studies had the same working principle as the clinically used devices. However, the assembly and algorithm were more straightforward and inexpensive compared to the clinically used devices.

RESULTS

A Brief History of Respiratory Gating

Early studies on surface tracking in the human body harnessed the photogrammetry mapping technique. The principle of this technique was to track the position of a point on the human skin surface. Furthermore, it leveraged the parallax principle to estimate the depth of some regions. This technique has been implemented in medicine as an agreement in radiotherapy [14,15] and for detecting scoliosis [16]. According to previous studies, one of its major drawbacks is the inability to measure in real time.

In 1980, Parkin and Unsworth [17] were the first to use respiratory gating techniques in radiotherapy. The implementation of respiratory gating in the 1980s still used contact-based measurement to monitor chest or thoracic motion. The monitoring system was carried out with a Velcro band [18], plastic placed on the
Methods of Respiratory Gating in Radiotherapy Treatment

At present, there were only two respiratory gating methods in radiotherapy, where one involved the patient in the procedure, while the other did not. Furthermore, these two methods must be adjusted for each patient. Some individuals were cooperative enough to get involved in the procedure, while others with severe conditions did not require their involvement.

The first method, which did require the patient in the procedure was adaptive breathing. Several studies had shown that there were two types of adaptive breath, including deep inspiration breath hold (DIBH) and enhanced inspiration gating (EIG) [8]. The main objective of these methods was to eliminate the breathing motion to reduce the target volume within the margin inside. This was expected to improve the radiotherapy treatment and dose distribution accuracy [23]. DIBH was a method designed to assist patients in manipulating their breathing. In the DIBH method, the physician instructed the patient to hold their breath after inhaling (inspiration). During EIG, the patient breathed deeper beyond the normal level. Audio guidance was also placed in the room to inform individuals when to hold their breath or take a deeper breath. The chest cavity often widened in the inspiration position, thereby decreasing the mean radiation dose to the heart.

According to previous studies, the radiation dose to the lungs could also be reduced using the DIBH method. However, the feasibility and efficacy of these techniques varied between individuals due to anatomical differences. This indicated that optimal positioning reproducibility and verification were required to optimize the breath-hold methods [8,23,24].

The second method was free breathing (FB), where the patients were not required to hold their breath as in DIBH or breathe deeply as in EIG. The method primarily focused on the achievement of normal breathing. The irradiation was automatically turned on during a certain interval of the breathing cycle [24]. The FB technique was divided into two categories, including with and without gating. FB without gating required a larger margin to the target volume, while FB with gating used a reduced margin. For clarification purposes, “FB” refers as “FB with gating” in this review [8,25].

Several studies showed that DIBH was more often used compared to FB methods. In terms of dose distribution, DIBH was better at reducing OAR dosage. However, it was difficult for some patients with severe conditions, whose breath-holding or enhanced inspiration could be very challenging. These patients were not eligible for treatment with DIBH or EIG methods, leading to the preference for FB [1,25,26].

Respiratory Monitoring Devices

Physicians must use suitable methods to precisely and accurately position the tumor motion for respiratory gating. According to previous studies, two methods are typically used for treatment, including contact-based and non-contact-based monitoring. Contact-based monitoring refers to a device that “touches” or is “in contact” with the patient’s body, either on the chest or other body parts, where respiratory signs could be monitored. Meanwhile, non-contact-based monitoring referred to the device was not “in touch” or “in contact” with the patient’s body and was typically an optical-based variant. These two methods indirectly monitored the tumor motion and only measured physiological motion that correlated with the tumor. In this section, some of the devices used clinically are described.

It is important to note that there are two types of breathing motion, namely abdomen and chest. The type of breathing motion was related to the measurement method used by the device. Some devices only monitor a point or an area from the subject’s skin. Therefore, the instruments must be adjusted to the subject’s breathing type. This adjustment was essential due to the significant motion from the chest or abdomen area. Significant motion indicated a wide range of tumor motion that could be observed.

During inhalation, the rib cage widened, leading to the upward motion of the chest wall, while the opposite occurred in exhalation. This upward and downward motion was measured using respiratory monitoring devices. However, this movement was not just upward and downward, indicating that several devices must consider the widening of the rib cage. These devices commonly use optical flow to detect the widening movement [27–29].

Abdominal breathing occurs due to the push from the air inside the lungs, leading to the movement of the diaphragm toward the abdominal cavity. This indicated that there were some motions from the external perspective. Povšič et al. [30] showed that this abdominal breathing motion was dominant in male subjects.

The majority of studies monitoring the breathing movement focused on chest breathing because it had a significant interval and wider amplitude compared to abdominal breathing [30]. This was beneficial because it facilitated the observation of a wide range of tumor organ positions.
The Active Breathing Coordinator (ABC; Elekta AB, Stockholm, Sweden) used spirometry for contact-based monitoring, and it consisted of a spirometer and a valve. The spirometer measured the air volume from the patient’s lungs. Furthermore, spirometry often measures up to 70–80% of the maximum inspiration volume. Patients must undergo a preparation phase to confirm the lung’s air capacity. When the spirometer detected the optimal volume, the valve closed the air channel. However, the patient was also able to prevent the timed closure of the valve. Several studies have shown that the ABC system was very suitable for the DIBH method [1].

The Anzai Belt (Anzai Medical, Tokyo, Japan) uses a pressure sensor built into a stretchy belt. The device was wrapped around the chest or abdomen of the patient, thereby utilizing contact-based monitoring. The Anzai Belt detected the pressure from the patient’s breathing due to the spreading of the abdomen or chest. Furthermore, the pressure represented the respiratory rate of individuals. Although it was less invasive compared to ionization-based monitoring, this device was not convenient for all individuals [31].

The Real-Time Position Management (RPM; Varian Medical Systems, Palo Alto, CA, USA) used a surrogate box to represent the breathing motion. Physicians positioned this surrogate using tape and marked the position with a skin tattoo [3]. The device consisted of reflective markers that reflected infrared light onto the charge-coupled device (CCD) camera. The camera was often placed by the technologist in a fixed position relative to the breathing motion. Furthermore, it was connected to the computer, which was in connection with the Linac. The movement of the surrogate box was analyzed in real time by software to trigger the Linac to the predefined gate [1]. This device was a form of contact-based monitoring because the surrogate box had been placed on the patient’s body.

Catalyst (C-Rad AB, Uppsala, Sweden) was an optical surface scanner that used projected visible light and a CCD camera. The visible light was often obtained from three high-power LEDs in blue, green, and red, with wavelengths of 405, 528, and 624 nm, respectively. The blue light was used to measure and scan the surface, while the green and red lights were utilized to identify surface mismatches according to the reference. Catalyst projected the visible lights onto the surface, and the CCD camera captured these lights. Furthermore, this device measured the surfaces based on the triangulation principle. The system was mainly used for patient positioning before treatment and monitoring during treatment. Based on previous studies, the catalyst had a motion accuracy of < 0.5 mm [32,33].

AlignRT (VisionRT, London, United Kingdom) had a similar working principle to Catalyst, and its assembly consisted of three modules. The first module projected a light with a speckle pattern, while the second and third modules, containing a camera, detected the projected light. Furthermore, the light was reconstructed to transform it into a copy of the subject’s surface. In terms of performance, AlignRT was similar to Catalyst, as reported by previous. Furthermore, both devices could perform surface tracking up to a sub-millimeter scale with six degrees of freedom, process the data in real time, and were non-invasive instruments that did not give additional radiation to the subject [34–37].

AZ-733VI (Anzai Medical) was a laser-based sensor for breathing monitoring. This device measured the distance between the laser and the body’s surface, which could be a point in the sternum or the abdomen. Laser Distance Sensor (LDS) measured the angle differences in the light reflected off the target passed to the receiver. The angle was proportional to the distance between the laser and the surface. Furthermore, the laser sensor detected the diffuse-type reflection. When implemented in breathing monitoring, this device must be assembled perpendicular to the surface to ensure the measurement was effective. Correction factors could be applied when a perpendicular surface was hard to achieve [38].

Recent Developments

Several radiotherapy facility centers commonly use laser sensors to monitor the breathing motion derived from the distance measurement. This type of device was also used in clinical radiotherapy treatment. In radiotherapy, this method was utilized for verifying the patient’s position and accurately delivering the treatment beam to the patient. The latter was the critical implementation of breathing monitoring devices.

A total of 3 studies investigated breathing motion using laser devices based on the same working principle [31,38,39]. Figure 1 provides the working principle of the instruments used in these studies. Laser-based devices have a similar working mechanism to AZ-733VI. Kim et al. [39] and Jensen et al. [38] compared a laser-based device to a clinically used device, namely RPM by Varian and Catalyst by C-Rad, respectively. The two studies showed that laser-based devices had high performance when used in clinical conditions. Farzaneh et al. [31] comprehensively designed and constructed a laser-based breathing monitoring instrument, including the electronic circuits, assembly hardware (box holder and LCD holder), software for processing the signal, and phantom.

Apart from laser-based devices, other studies have investigated breathing motion using dual cameras [40,41]. Figure 2 provides an illustration and comparison of the studies by Leduc et al. [41] and Barbés et al. [40].

Although the same dual camera was utilized, these studies had different working principles. Barbés et al. [40] used two cameras attached to the bunker wall at a distance of 4 m. The distance and height from the
of motion-based processing using a single camera had been reported to be unable to capture the distance, thereby necessitating another technique. The human body’s respiratory rate was detected and extracted, turning it into a signal.

The aim of the papers included in this review was similar, but some reports were more accurate in terms of radiotherapy purposes. However, it was important to note that better accuracy required greater computational cost, leading to a decrease in efficiency and effectiveness. Some devices could not monitor in real-time due to their computational complexity. Studies using cameras tended to use either the algorithm by Viola-Jones [12–15] or YOLO [16] to automatically detect the ROI. Several studies have also used the KLT algorithm to track slight motions to stabilize the ROI for real-time measurement [12–15, 17]. Meanwhile, studies on respiratory gating devices are summarized in Table 1.

Table 1 shows that there were two kinds of processing, namely depth information and motion-based. Studies monitoring breathing motion were not limited to the five provided in Table 1. Several reports monitored breathing motion by implementing other systems apart from respiratory gating, as shown in Table 2.

Table 2 shows that there were two kinds of processing, namely depth information and motion-based. Depth information processing followed the same principle as laser distance sensors by measuring breathing motion based on the distance between the subject’s surface and the laser. Depth camera devices had at least two cameras. Furthermore, these two cameras could combine the two visuals, which were then used to calculate the distance between the subject’s surface and the camera. The use of motion-based processing using a single camera had been reported to be unable to capture the distance, thereby necessitating another technique. The human body’s respiratory rate was detected and extracted, turning it into a signal.

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Kumagai et al. [10] and Wijenayake and Park [9] used a single RGB-Depth (RGB-D) camera to monitor the motion from the subject’s surface. Kumagai et al. [10] utilized Kinect (Microsoft, Redmond, Washington, United States) to monitor the intrafraction motion from the thoracic and abdominal areas. Furthermore, Ueda’s algorithm was employed in this study to reduce the
### Table 1. Breathing monitoring studies specifically for respiratory gating

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Device</th>
<th>Subjects</th>
<th>ROI</th>
<th>Results</th>
<th>Comparison Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jensen et al., 2016 [38]</td>
<td>Laser distance sensor</td>
<td>7 healthy volunteers</td>
<td>Point on chest</td>
<td>Mean ratio = 1.51</td>
<td>Catalyst system</td>
</tr>
<tr>
<td>Farzaneh et al., 2018 [31]</td>
<td>Laser distance sensor</td>
<td>In-house phantom</td>
<td>Point on phantom’s surface</td>
<td>Linearity = 1.00</td>
<td>Actual measurement of the in-house phantom</td>
</tr>
<tr>
<td>Kim et al., 2021 [39]</td>
<td>Laser distance sensor</td>
<td>5 healthy volunteers</td>
<td>Point on chest</td>
<td>Mean correlation coefficient (DIBH) = 0.98</td>
<td>Real-time position management</td>
</tr>
<tr>
<td>Barbès et al., 2015 [40]</td>
<td>Dual camera</td>
<td>23 patients (21 breast tumor, 1 lung tumor, and 1 bladder tumor)</td>
<td>1–3 points on the patient’s surface</td>
<td>Relative precision ≤ 0.3 mm</td>
<td>Anzai System</td>
</tr>
<tr>
<td>Leduc et al., 2016 [41]</td>
<td>Dual camera</td>
<td>In-house phantom’s breast</td>
<td>3 points on phantom’s breast</td>
<td>Correlation coefficient = 0.992–0.999</td>
<td>Actual measurement of the in-house phantom’s breast</td>
</tr>
</tbody>
</table>

Note – ROI = Region of Interest

### Table 2. Breathing monitoring studies for general medical purposes

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Device</th>
<th>Processing</th>
<th>ROI</th>
<th>Comparison Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Naji and Chahl, 2016 [42]</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Manual measurement</td>
</tr>
<tr>
<td>Bodilovski and Popov, 2017 [43]</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Capnograph</td>
</tr>
<tr>
<td>Braun et al., 2017 [44]</td>
<td>RGB camera and NIR camera</td>
<td>Motion-based</td>
<td>Abdomen</td>
<td>Belt measuring system</td>
</tr>
<tr>
<td>Brieva et al., 2020 [45]</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Manual measurement</td>
</tr>
<tr>
<td>Gleichauf et al., 2020 [46]</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Abdomen</td>
<td>Manual measurement</td>
</tr>
<tr>
<td>Janssen et al., 2015 [27]</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Abdomen</td>
<td>ECG</td>
</tr>
<tr>
<td>Jorge et al., 2017 [47]</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Abdomen</td>
<td>Clinical monitoring</td>
</tr>
<tr>
<td>Kumagai et al., 2016 [10]</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Chest</td>
<td>Anzai Belt</td>
</tr>
<tr>
<td>Lee et al., 2021 [48]</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Abdomen</td>
<td>Clinical monitoring</td>
</tr>
<tr>
<td>Marchionni et al., 2013 [49]</td>
<td>Laser distance sensor</td>
<td>Motion-based</td>
<td>Chest</td>
<td>ECG and spirometer</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Device</td>
<td>Processing</td>
<td>ROI</td>
<td>Comparison Device</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td>Massaroni et al.</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Breathing pressure measurer</td>
</tr>
<tr>
<td>Mateu-Mateus, 2021</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>RespiBand (PLUX wireless biosignals S.A., Portugal)</td>
</tr>
<tr>
<td>Nam et al., 2016</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Abdomen</td>
<td>Chest belt sensors</td>
</tr>
<tr>
<td>Nazir et al., 2020</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Abdomen</td>
<td>Ventilator</td>
</tr>
<tr>
<td>Paz-Reyes et al. 2019</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Thermistor</td>
</tr>
<tr>
<td>Povič et al., 2012</td>
<td>RGB camera</td>
<td>Depth information</td>
<td>Chest</td>
<td>Spirometer and calibration syringe</td>
</tr>
<tr>
<td>Reyes et al., 2017</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Spirometer</td>
</tr>
<tr>
<td>Romano et al., 2021</td>
<td>RGB camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Measuring belt plethysmograph</td>
</tr>
<tr>
<td>Sun et al., 2019</td>
<td>Monochrome camera</td>
<td>Motion-based</td>
<td>Chest</td>
<td>Chest impedance</td>
</tr>
<tr>
<td>Tahavori et al., 2015</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Chest</td>
<td>Dynamic Thorax Phantom Model 008A (Computerized Imaging Reference Systems, Inc., Norfolk, Virginia, United States)</td>
</tr>
<tr>
<td>Wang et al., 2020</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Abdomen</td>
<td>Spirometer</td>
</tr>
<tr>
<td>Wijenayake and Park, 2017</td>
<td>Depth camera</td>
<td>Depth information</td>
<td>Abdomen</td>
<td>Spirometer and laser line scanning</td>
</tr>
</tbody>
</table>

Note – RGB = Red, Green, and Blue Wavelength; NIR = Near Infrared; ECG = Electrocardiogram

signal noise. The results correlated with measurements using the Anzai Belt for thoracic and abdominal areas. Wijenayake and Park [9] used Xtion (Asus, Beitou, Taipei) to monitor breathing motion in the same regions. The results were then compared with a spirometry device and a similar respiratory pattern was produced.

Breathing monitoring devices detected the external motion from the subject, rather than the individual's internal tumor or organ motion. However, those external motion could be correlated to the internal motion using a motion model [35].

Accurately detecting breathing motion was crucial because the radiation beam must be delivered precisely and accurately to ensure the delivery of an optimal dose. Respiratory motion was a significant source of target uncertainty in radiotherapy treatment, especially in thoracic and abdominal tumors. Accuracy and precision in the measurement of breathing motion were important, especially in the FB technique due to its unstable respiration rates compared to the breath-hold technique, which had a more stable rate.

**DISCUSSION**

In this review, two types of devices, namely lasers, and cameras, utilized the non-contact-based monitoring principle. The advantages of lasers were their simplicity and potentially low cost due to the low-profile work principle. However, they could not track the intrafraction motion, which was also important in radiation therapy treatment.

This drawback could be addressed through the utilization of a camera. The clinical device Catalyst had also been reported to use this work principle, and cameras were superior to lasers in terms of accuracy. However, camera-based devices had a drawback, due to their complexity compared to a laser. Camera devices often require more than one module, such as a dual camera or a camera and light projector. At least two modules were used to give Catalyst and other similar devices a view from the gantry or Linac head to provide different angles.
The future development of breathing monitoring devices was expected to combine the advantages of the functionality of lasers and cameras. The devices were expected to have a lower cost due to the simplicity of lasers’ working principle but also give intrafraction motion based on the cameras’ principle. This innovation used a laser to track the anterior-posterior direction and a camera to track the motion in superior-inferior and lateral positions. Compared to the weaknesses of the laser device, this future device could track the intrafraction motion. Furthermore, only one camera was needed, striking out the need to add another to the system.

CONCLUSIONS

Motion during radiotherapy treatment could affect the accuracy of the radiation beam. Compensating these motions could be carried out using respiratory gating devices. Several studies have shown that respiratory gating could provide several advantages to patients, especially in the dosimetric aspect, such as better tumor organ treatment and reduced toxicity to healthy organs. These benefits could give lung, breast, liver, and other respiratory-related cancer patients a longer life expectancy. Furthermore, it was found that apart from the dosimetric aspect, the development of the respiratory gating device also paid attention to the patient’s comfort during treatment. This was indicated by the non-contact nature of the recent development. The respiratory gating device must also consider the mechanical aspect, where it has to measure the motion of the patient’s breathing accurately. Advancements in current technology could be implemented in future respiratory gating devices.

DECLARATIONS

Competing interest
The author(s) declare no competing interest in this study.

Ethics approval
We have not submitted ethical clearance yet.

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