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UT Southwestern Medical Center

VETERINARY RESEARCH AND ONCOLOGY CLINIC

A Low-Cost Belt-Based Respiratory Gating System for Veterinary Radiotherapy

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KEY FINDINGS

- **<$500** Total hardware cost — Low-cost & affordable
- **≤250 ms** Gating latency (beam on)
- **≈100%** Gamma passing rate (3%/2mm)
- Veterinary-specific solution
- Open & user-friendly architecture
- Compatible with Elekta Linacs

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Introduction

- Motion management plays a critical role in radiation therapy for thoracic and abdominal tumors, where respiratory motion can significantly compromise treatment precision.
- Among available motion-mitigation techniques, respiratory gating offers distinct advantages for anesthetized veterinary patients.
- However, the high cost and proprietary nature of commercial respiratory-gating systems designed for human use pose significant barriers to adoption in veterinary clinics, where capital resources are typically limited.

Aims

- Aim 1: To develop a low-cost, user-friendly, and patentable respiratory gating system that is compatible with the Elekta linear accelerators.
- Aim 2: To investigate the beam on and off latencies of the respiratory gating system.
- Aim 3: To study the impact of different respiratory cycles on gated dose delivery accuracy

Materials and Methods

Schematics of the respiratory gating system

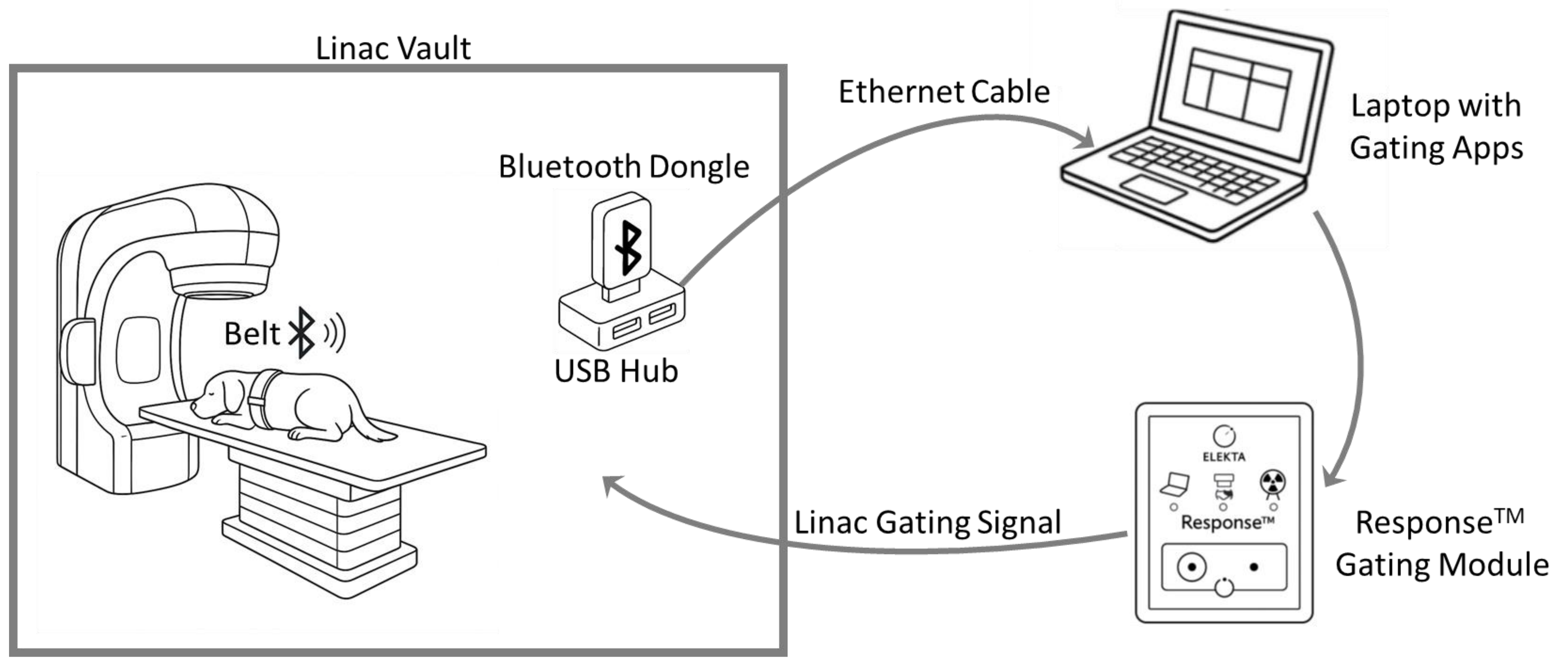

Figure 1. Layout of the respiratory gating system. A Vernier Go Direct respiratory belt sends respiratory signal via Bluetooth. The signal is received by a Bluetooth dongle that is remotely connected with a laptop at treatment console via an USB hub and ethernet cable. An in-house developed Python script then processes the signal and generates triggering signal that is sent to the Response™ gating module for gated radiation delivery on the linac.

VSyncBreath: A Python Software for the Gating System

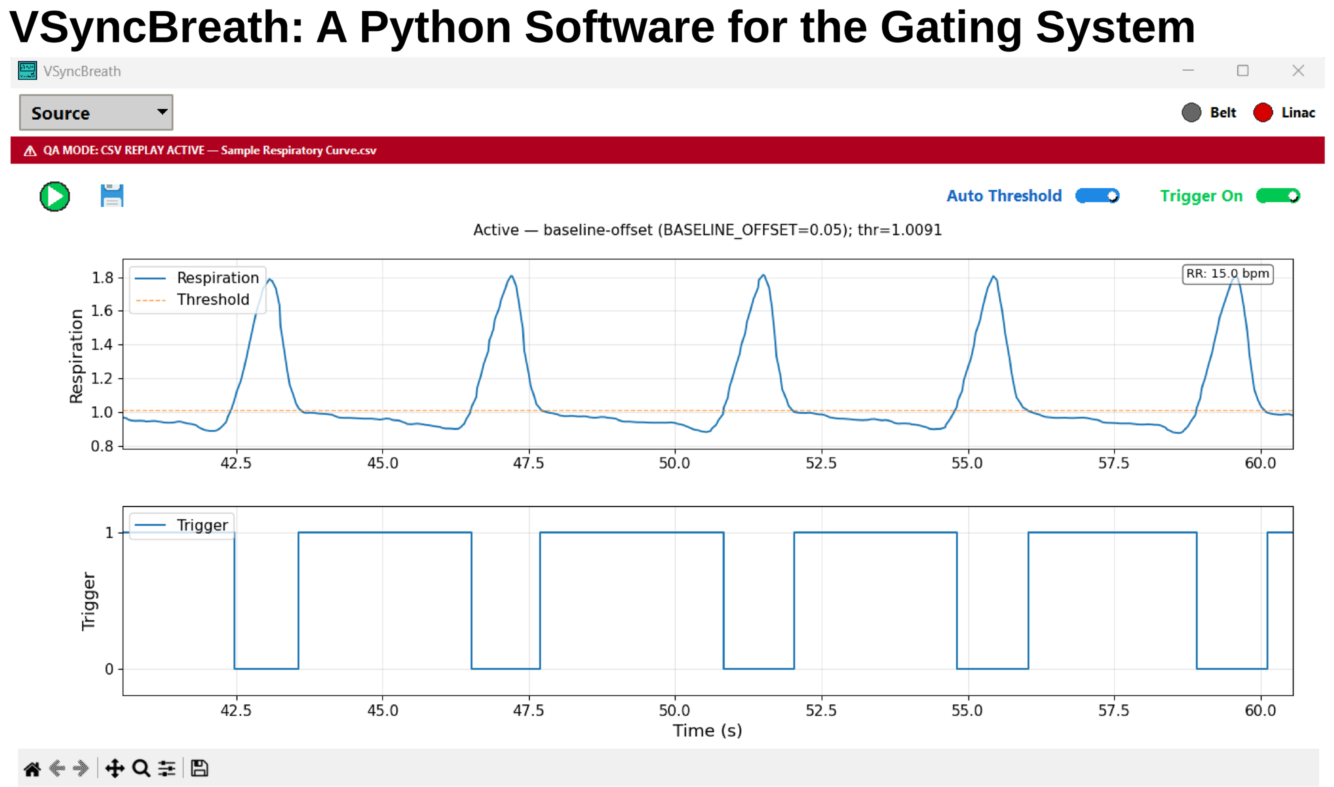

Figure 2. VSyncBreath software. Three signal sources are available: live, simulation, and replay. In live mode, it captures real-time respiratory signal via Bluetooth. The acquired signal is displayed dynamically along with the trigger signal set to allow beam on at the end of expiration. Users have the options to use automatic or manual threshold, and enable or disable the trigger signal.

Gating Latency Measurement with A Motion Phantom

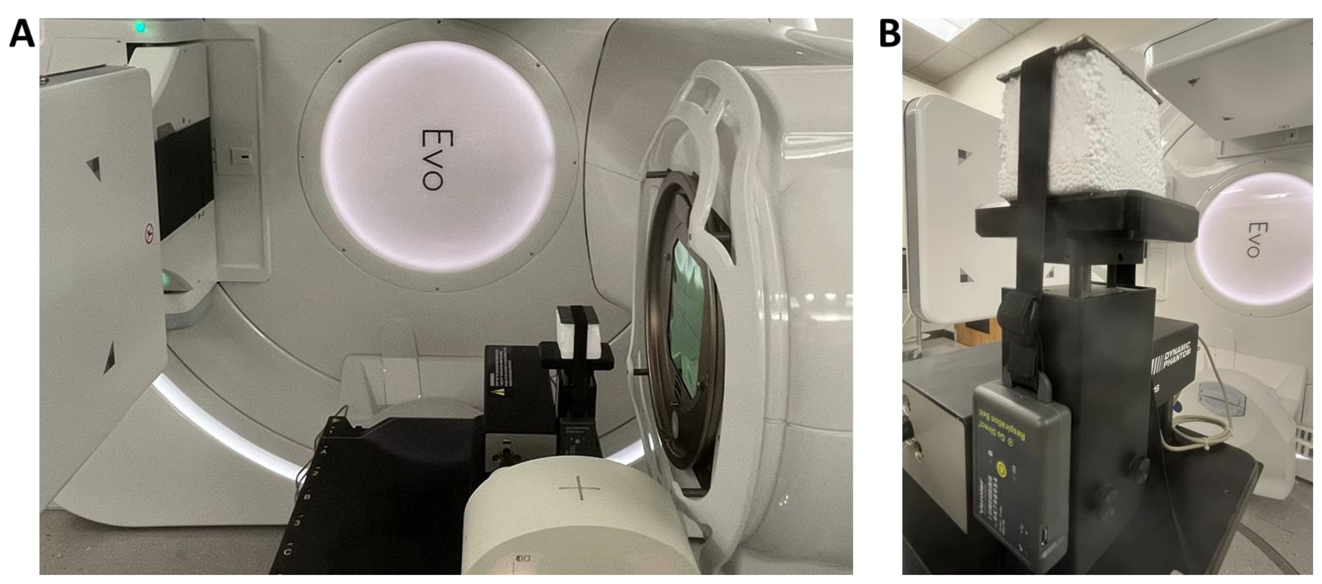

Figure 3. Experimental setup for gating latency measurement. A CIRS dynamic thorax phantom was used to generate periodic sawtooth motion of a 2-mm-thick lead piece supported by a foam block on the surrogate platform (**A**). The phantom was positioned close to the linac gantry head. The respiratory belt was placed around the surrogate platform for motion tracking. (**B**). Megavoltage portal images were acquired with the lead piece at the origin with the platform in static position, serving as a reference location. With the lead piece in periodic motion on the surrogate platform, MV images were taken during initial and last moments of beam on period. Then the beam on and off lags were calculated based on the deviations of the lead piece position from the static position.

Materials and Methods (continued)

IMRT QA With and Without Gating

- VMAT plans (n=5) delivered with and without respiratory gating with respiratory period at 3 and 6 seconds, respectively
- Gamma passing rate quantification
  - Gated vs non-gated, 2%/1mm
  - Gated vs TPS, 3%/2mm

Results

Respiratory Signal Tracing Accuracy

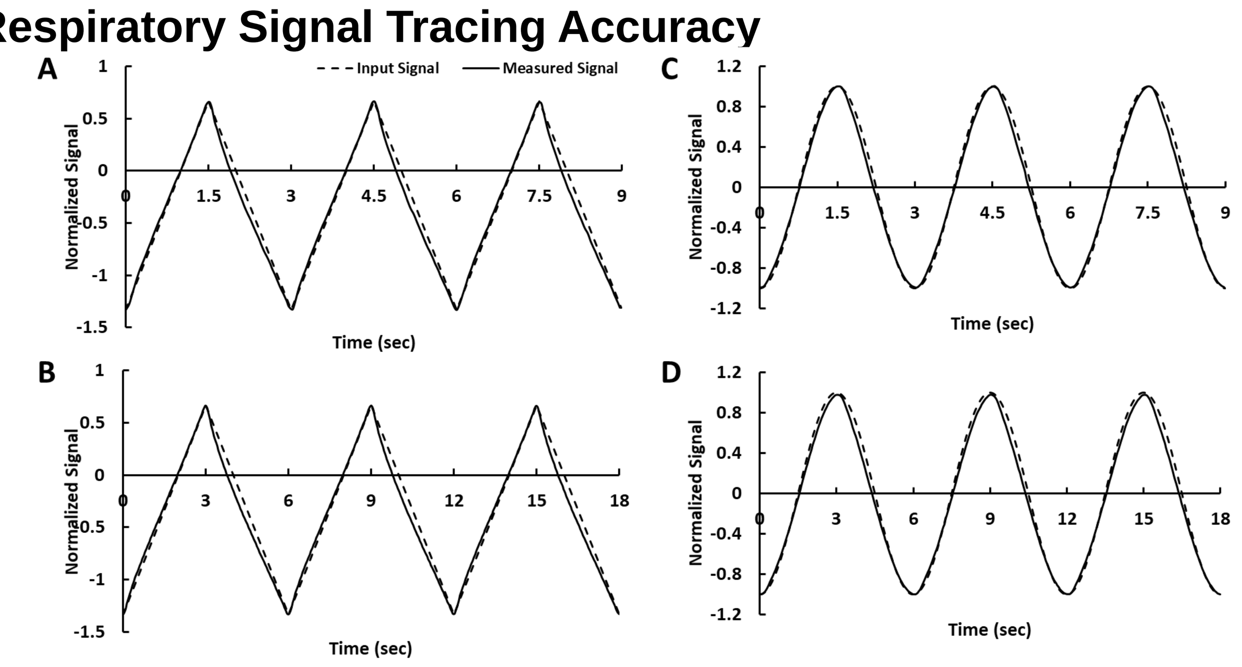

Figure 4. The input and measured sawtooth and sinusoidal curves cycled at 3 and 6 seconds, respectively.

Results (continued)

Gating Latency Measurement

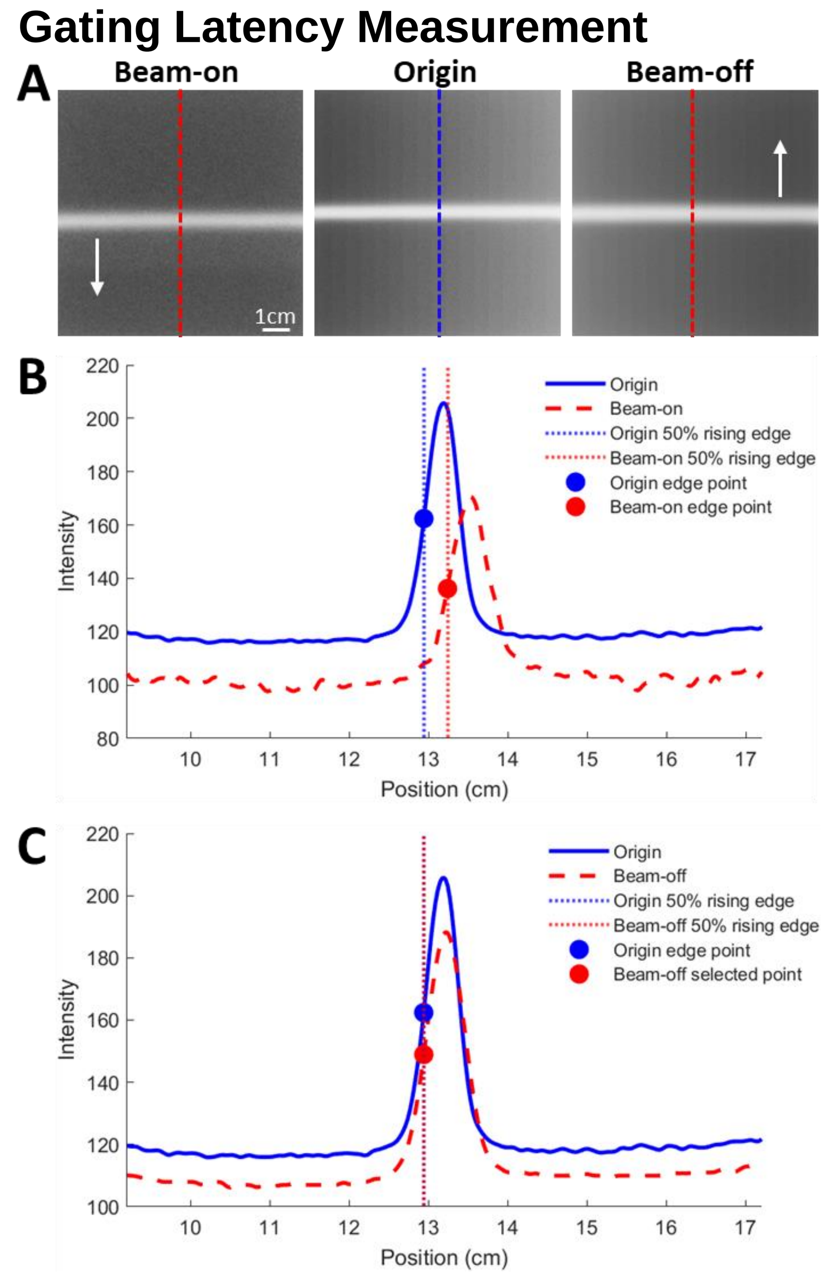

Figure 5. Gating latency measurement on acquired MV images. (A) MV portal images acquired with the lead piece at beam on (left), at the origin (middle), and right before beam off (right). The arrows shows the lead piece movement direction. The dotted lines shows where the line profiles were taken for gating latency quantification. **(B-C)** The extracted lines profiles corresponding to the lead piece position in **A** are shown. The dotted lines indicate where the 50% signal from their respective baseline values, with the dots showing the position of these dotted lines. The differences between the blue and red dots were used to calculate the beam on and off lags.

Table 1. Gating latencies.

Motion period (sec)	Gate-on latency (ms)		Gate-off latency (ms)	
	6MV	6MV-FFF	6MV	6MV-FFF
3	136.3 ± 25.5	276.6 ± 25.8	13.4 ± 10.1	26.3 ± 17.8
6	254.2 ± 19.4	149.8± 20.7	51.6 ± 18.5	24.9 ± 19.1

Gated Delivery Dose Accuracy

Table 2. Gamma passing rates showing the accurate dose delivery with respiratory gating.

	Beam	3s Gate vs. No-Gate (%)	6s Gate vs. No-Gate (%)
Measured vs. Measured (2%/1mm)	6X	98.2 [89.4–99.6]	100.0 [100.0–100.0]
	6FFF	100.0 [99.4–100.0]	100.0 [100.0–100.0]
	Beam	**3s Gate vs. TPS (%)**	**6s Gate vs. TPS (%)**
Measured vs. Calculated (3%/2mm)	6X	100.0 [91.6–100.0]	100.0 [98.3–100.0]
	6FFF	100.0 [99.5–100.0]	100.0 [99.4–100.0]

Discussion and Conclusion

- The measured belt signal closely followed the imposed phantom motion during the expansion phase but showed a small deviation during the contraction phase. This asymmetry is likely due to the mechanical hysteresis and relaxation behavior of the elastic belt–sensor system.
- Beam-on latency is not constant but varies with respiratory period and beam energy. In contrast, gate-off latency remained relatively stable across all investigated conditions, indicating that beam interruption can be achieved rapidly by suppressing subsequent pulse generation.
- Reliable dose deliveries are demonstrated by comparing gated dose with non-gated dose and TPS.
- A low-cost, user-friendly, and low-latency respiratory gating system compatible with Elekta linear accelerators was successfully developed and validated.