ORIGINAL RESEARCH

Feasibility of Live Video Feed Transmission from Unmanned Aerial Vehicles for Medical Surveillance During the 2022 Montreal Marathon

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Abbreviations:
FOV: field of view
SCA: sudden cardiac arrest
UAV: unmanned aerial vehicle

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Abstract

Introduction: In recent years, unmanned aerial vehicles (UAVs) have been increasingly used for medical surveillance purposes in mass-gathering events. No studies have investigated the reliability of live video transmission from UAVs for accurate identification of distressed race participants in need of medical attention. The aim of this study was to determine the proportion of time during which live medical surveillance UAV video feed was successfully transmitted and considered of sufficient quality to identify acute illness in runners participating in the 2022 Montreal Marathon (Canada).

Methods: Four UAVs equipped with high-resolution cameras were deployed at two pre-defined high-risk areas for medical incidents located within the last 500 meters of the race. The video footage was transmitted in real-time during four consecutive hours to a remote viewing station where four research assistants monitored it on large screens. Interruptions in live feed transmission and moments with inadequate field of view (FOV) on runners were documented.

Results: On September 25, 2022, a total of 6,916 athletes ran during the Montreal Marathon and Half Marathon. Out of the eight hours of video footage analyzed (four hours per high-risk area), 91.7% represented uninterrupted live video feed with an adequate view of the runners passing through the high-risk areas. There was a total of 18 live feed interruptions leading to a total interruption time of 22 minutes and 19 seconds (median interruption time of 32 seconds) and eight distinct moments with inadequate FOV on runners which accounted for 17 minutes and 33 seconds (median of 1 minute 47 seconds per moments with inadequate FOV). Active surveillance of drone-captured footage allowed early identification of two race participants in need of medical attention. Appropriate resources were dispatched, and UAV repositioning allowed for real-time viewing of the medical response.

Conclusion: Live video transmission from UAVs for medical surveillance of runners passing through higher risk segments of a marathon for four consecutive hours is feasible. Live feed interruptions and moments with inadequate FOV could be minimized through practice and additional equipment redundancy.

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Introduction

In recent years, use of unmanned aerial vehicles (UAVs), or drones, has gained popularity as a medical surveillance tool in mass-gathering events and sporting competitions.[1,2] These remotely piloted aircraft have been hypothesized to allow for faster and more accurate detection of medical incidents, and their use in delivering crucial medical supplies such as blood products and automated external defibrillators (AEDs) have shown promising results.[3–6] The feasibility of using drones to identify early signs of distress in swimmers participating in an Ironman race has been studied.[1] No studies have investigated the reliability of live video transmission from UAVs for accurate identification of distressed marathon runners in need of medical attention.

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Marathons are 42.2-kilometer-long running races that attract millions of athletes every year. Various medical pathologies are witnessed during these events, from minor musculoskeletal injuries all the way to sudden cardiac arrest (SCA).[7,8] The incidence of SCA suffered by runners during marathons is 1.01 per 100,000 participants (0.27 per 100,000 participants for half marathons), most of which occur within the final kilometers of the race.[9] Prompt and definitive management of SCA has been shown to improve outcomes and survival.[10,11] Therefore, such events require a high level of medical organization to identify athletes in distress, dispatch appropriate resources, and provide appropriate care.

Transmission of live video feed captured on the field to a remote-control center where footage can be monitored by dedicated personnel involves an intricate multi-step process. As a result of this, there is room for many possible mishaps along this chain of transmission, including hardware, software, and network malfunction. One must also consider uncontrollable meteorological factors such as rain, high winds, and extreme heat which may lead to forced emergency landing of the drones and compromise surveillance operations.

The aim of this study was to determine the proportion of time during which live medical surveillance UAV video feed was successfully transmitted and considered of sufficient quality to identify acute illness in runners participating in the 2022 Montreal Marathon (Canada).

Methods

Study Design and Setting

This prospective observational study was conducted during the 2022 Montreal Marathon, held on September 25, 2022. The McGill University Health Centre (Montreal, Canada) Research Ethics Board exempted this study from review because it involves observation of people in a public area, the research team did not get involved in any interventions, and the dissemination of research results does not allow identification of specific individuals.

Identification of Safe and Relevant Surveillance Areas

Prior to the race, the team gathered to identify two "high-risk" areas for medical incidents that were also suitable for UAV surveillance. The "downhill" and "uphill" segments (Figure 1), located within the last 500 meters of the race, were selected because their uneven terrains were judged to increase the risk of injuries as fatigued participants ran through them. Furthermore, the nature of these areas made them less accessible for identification and response by medical teams for participants in distress. Early detection of runners suffering a medical problem in "high-risk" areas using UAVs could improve the overall response time. Finally, this location was ideal for UAV video monitoring as it allowed a clear, continuous, and overlapping line of sight on runners.

Equipment and Live Video Footage Transmission

Four DJI Mini 2 (DJI Sky City; Shenzhen, China) were used for data collection. These commercially available UAVs weigh 249 grams, are equipped with high-resolution cameras capable of 4K video footage, and have an advertised flight time of up to 31 minutes. To accommodate a total flight time of eight hours (four hours per segment), the team had an extra set of 15 DJI Mini 2 batteries alongside five "DJI Two Way Charging Hubs," each of them capable of charging up to three batteries simultaneously. Drone pilots used their smartphones as remote controls to pilot the UAVs. Phones were recharged using 10,000mAh power banks. Live video footage captured from the UAVs was broadcasted from the pilots' phones via cellular LTE network. Remotely, the team had access to computers connected to high-speed WiFi (WiFi 5 network with a 200/200 Mbps hybrid capacity) and the live footage was displayed on large screens for active monitoring. Communication between the drone pilots and the research team was established via text messages and phone calls.

Safety Precautions

The drone pilots involved in this study held a valid and up to date "advanced operations pilot certificate." To ensure the participants' and crowd's safety, drone takeoffs and landings were done at a remote site to minimize bystander interference. Furthermore, the drones' flight paths and pre-determined hovering areas were never directly above crowds or participants, such that in the event of an emergency landing, the safety of bystanders would not be compromised. This study was conducted in concordance with Transport Canada (Ottawa, Canada) regulations.

Surveillance of Runners Using UAVs

Two drones were deployed at any given time (one per segment), requiring two distinct pilots. After 25-30 minutes of flight time, pilots were notified by their UAV of a low battery status. In-air drone swaps were performed to minimize loss of video signal. With the help of a third pilot, a UAV with a fully charged battery flew to the appropriate location. Once adequate field of view (FOV) on runners from the third UAV was confirmed by the team, the "low battery" UAV would turn off its video transmission and return to the drone crew location, where it would safely land and have its battery swapped. The pilot would then rest until another in-air swap was required. During the design of this study, it was decided that if a runner in distress was identified within close range, an in-flight UAV would safely relocate to capture the incident, allowing real-time monitoring of the medical response and leaving one of the high-risk zones unsupervised.

Data Collection and Reporting

A team of four research assistants were responsible for data collection at a remote location. Two members monitored live video footage from the "uphill" or "downhill" segments, respectively, and identified brief interruptions in signal transmission (less than three seconds), moments of live feed interruptions, or inadequate FOV on runners. The other two members were responsible for documentation of the duration and details surrounding these events. When runners in distress were identified, a member of the team notified the medical team with the exact location of the runner and contacted the pilot team to ensure adequate UAV re-positioning to monitor the incident. The timing and circumstances of the medical incidents were recorded.

Results

There were 1,793 and 5,123 participants at the 2022 Montreal Marathon in the 42.2km and 21.1km races, respectively, for a total of 6,916 runners. Participants running through the "uphill" and "downhill" segments were monitored remotely via live video analysis recorded by UAVs over a four-hour period.

Events that interfered with the team's ability to actively survey runners were documented as either "live feed interruptions" or "inadequate field of view" (Figure 2). Brief interruptions were documented as a separate entity as the short nature of these interruptions (less than three seconds) was judged not to interfere with monitoring of athletes (Figure 2). There were 199 insignificant brief interruptions during the total eight hours of

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Figure 1. Aerial Map of UAV Operating Locations with View of High-Risk Segments Captured from UAVs.
Abbreviation: UAV, unmanned aerial vehicle.

video footage captured. Feed loss was the most common reason for these interruptions, totaling 175 events. Other reasons for these interruptions included losing signal due to the computers screen saver turning on (19 events) or interruption in the broadcast from the drone pilot's phone (ie, due to an incoming phone call or software malfunction; five events).

Longer interruptions occurred for a total of 39 minutes 52 seconds, representing 8.3% of the total eight hours of live footage recorded (Figure 2). There were 18 significant live feed interruptions (22 minutes 19 seconds; 4.65% of total) and eight moments with inadequate FOV (17 minutes 33 seconds; 3.65% of total), with similar length of interruptions between the uphill and downhill portions (Figure 2). The median length of live feed interruption was 32 seconds, with the longest being 6 minutes 40 seconds and shortest being 15 seconds (data not shown). The average inadequate FOV was 1 minute 47 seconds, with the longest being 6 minutes 44 seconds and the shortest being 38 seconds (data not shown). These interruptions were caused by various unforeseen factors. One-half of the live feed interruptions were caused by loss of signal, while other causes included poor coordination of in-flight drone swaps or a low-quality image that was unfit for monitoring of runners. Inadequate FOV was most commonly due to one drone relocating to visualize a medical incident, leaving either the uphill or downhill segment unsupervised.

Through active surveillance of runners, the team identified two participants in need of medical attention for which appropriate medical personnel was dispatched (Figure 2D). Six false alarms were also identified, defined as runners coming to a full stop for less than 10 seconds and restarting the race without further assistance (Figure 2). During those eight events, an in-flight drone was relocated to enhance visualization of athletes in distress and visualize on-site medical response when necessary.

Discussion

This pilot study represents the first investigation of the feasibility of using UAVs for monitoring of race participants during a marathon. The team analyzed eight hours of live video footage, monitoring 6,916 participants who ran the 2022 Montreal Marathon. In total, 91.7% (7:20:08) of the video footage captured was deemed adequate for active surveillance of athletes. Most of the live feed interruptions or moments with inadequate FOV on runners were due to network issues or relocation of in-flight UAVs to record medical incidents, respectively. In a future setting where UAV live video footage monitoring could potentially replace the traditional on-ground team for surveillance of athletes, strategies must be implemented to minimize interruptions, as those can lead to non-identification of athletes and a delayed medical response.

Relocating the surveillance team within close range of the drone pilots could potentially limit live feed interruptions due to network issues. The video footage captured from UAVs could then be streamed directly onto large monitors via either Bluetooth, direct WiFi, or a wired connection which would decrease latency, increase image quality, and bypass the need to stream the footage via cellular network.

Some of the moments with inadequate FOV on runners were either due to failed in-flight drone swaps or drone relocation to visualize medical incidents. Additional practice for in-flight drone swaps prior to the event could have limited the number of failed swaps. Furthermore, to minimize the frequency of swaps, alternate drones with longer battery life could be used, such as the S-CLOUD (Robotics Innovatory, School of Mechanical Engineering, Sungkyunkwan University; Seoul, South Korea), which has an advertised flight time of over 60 minutes, is made of soft material, and is deemed safe to fly over crowds.[12] Finally, with additional resources, a dedicated "medical incident drone response team," which is a specialized team of drone pilots and surveillance

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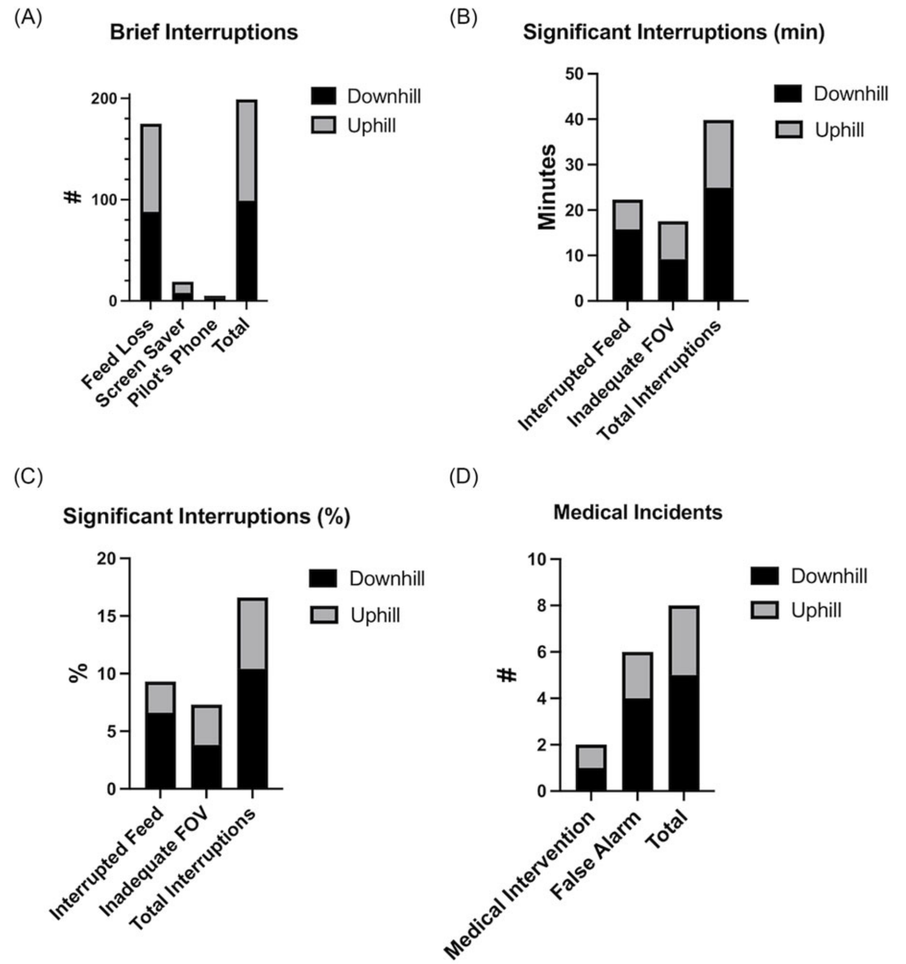

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Figure 2. Data Collection from UAV Surveillance of "Uphill" and "Downhill" High-Risk Areas. **(A)** Brief Interruptions (<three seconds). **(B)** Live Feed Interruptions and Moments of Inadequate FOV in Minutes. **(C)** Relative Live Feed Interruptions and Moments of Inadequate FOV on Total Data Collection Time. **(D)** Recorded Medical Incidents Leading to Medical Intervention or Labeled as "False Alarms" through UAV Surveillance.
Abbreviations: UAV, unmanned aerial vehicle; FOV, field of view.

personnel, could be deployed when a medical incident occurs. This team would actively monitor the injured athlete via UAV captured live video footage. This redundancy within the system would allow on-going good visualization of runners passing through high-risk areas rather than relocating to record medical incidents and leaving the high-risk areas unmonitored.

During the eight hours of live footage captured, the team identified two participants in need of medical assistance and six false alarms. This confirms the feasibility of using UAVs for medical surveillance of runners, although its effectiveness compared to the classic "on-ground" surveillance system would have to be determined in a further study. Close observation of participants who came to a full stop for a total of 10 seconds allowed the surveillance team to successfully triage runners in need of medical assistance from those resting or catching their breath (labeled as "false alarms"). This was important in preventing inappropriate dispatching of on-ground medical crews towards uninjured runners. Deep learning models to detect humans in high-traffic areas using video footage from UAVs have been recently developed.[13] With further improvements, these models could be a useful aid in identification of runners in distress in contexts similar to this study.

Some of the current challenges in expanding the use of UAVs in mass-gathering medicine are the variability in flying conditions and safety concerns.[14,15] The meteorological conditions during the 2022 Montreal Marathon were good and allowed the recording and transmission of good quality images. The research team recognizes that the weather may impact the ability to monitor outdoor sporting events in the future. In terms of safety, there were no incidents related to UAV use that occurred during the study. Pilots and their devices remained outside the race course and spectator areas in order to prevent incidents. No emergency landing was necessary.

Limitations

The favorable weather conditions during the 2022 Montreal Marathon allowed for safe and optimal flight conditions. The target zone for UAV surveillance represented a small but higher-risk part of the course for race participants. The UAV surveillance

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model used in this study may not be applicable to certain events depending on the race layout, vegetation, location of crowds, and weather conditions. Other variable factors such as hardware function (UAVs, cellphones, batteries), connectivity (strength of cellular network and/or WiFi), and drone pilot experience may impact the proportion of adequate live video footage for effective surveillance of runners, thus potentially limiting the replicability of this study.

Conclusion

In this first study of its kind, the team successfully deployed UAVs for live video medical surveillance of runners at pre-determined high-risk areas during the 2022 Montreal Marathon. In total, 91.7% (7:20:08/8:00:00) of the live video footage was deemed of sufficient quality to actively survey athletes. Strategies to minimize live feed interruptions and moments with inadequate FOV on runners could be developed to maximize real-time monitoring of athletes. Furthermore, two runners in distress were identified by the research assistants watching the live video feed and this led to successful dispatching of appropriate medical resources. Further research is required to determine how to optimize the quality and utilization of the live video feed during marathon races and its potential to decrease the response time for participants in distress.

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