CAN AUTOGYROS BE UTILISED IN EMERGENCY MEDICAL SERVICES?

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ABSTRACT

Autogyros—also known as gyroplanes or gyrocopters—preceded the invention of the helicopter, marking the beginning of the rotorcraft era. They feature an unpowered rotor that relies on autorotation and a separate power-plant that provides forward thrust. Autogyros are capable of short take-offs, near-vertical landings, and slow-speed cruising, while also being more cost-effective to manufacture and maintain compared to helicopters. Despite these advantages, their inability to hover limits their applicability in certain missions, particularly in emergency medical services (EMS), where helicopters are commonly used. However, the potential of autogyros in such roles has not been systematically evaluated. This study presents a preliminary feasibility analysis of using autogyros in Helicopter Emergency Medical Services (HEMS). It investigates operational limitations and identifies scenarios in which autogyros could serve as a viable alternative. By analysing real-world HEMS mission profiles and comparing them with current autogyro performance capabilities, the study estimates the proportion of missions that autogyros could realistically undertake.

NOTATION

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Acronyms

EWF Empty Weight Fraction

GWAA Great Western Air Ambulance

HEMS Helicopter Emergency Medical Service

MTOW Maximum Take-off Weight

WBAA Wiltshire and Bath Air Ambulance

WNDLR Warwickshire, Northamptonshire and Derbyshire, Leicestershire and Rutland Air Ambulance

INTRODUCTION

Helicopters are typically used as part of Emergency Medical Responses, often times in situations where time is a critical factor to the patients chances of survival or in situations where a ground crew taking traditional ambulance transportation would struggle to access the emergency site. These services are often more expensive compared to traditional ground based options however provide the ability to perform missions that a ground crew would struggle with location-wise or time-wise (Refs. 1, 2). There is a large variance in these air ambulance missions and as such not all missions require the same capabilities. However, air ambulance services often do not have the space or budget for many different helicopters depending on mission as even the smallest of helicopters are expensive enough that they simply would not find value if only used for less critical missions (Ref. 3).

Autogyros are the type of rotorcraft that cannot hover but can fly at low speeds and land and take off at short distances. They are predominantly used for sport and leisure. Autogyro have previously been used in non-recreational applications such as the ELA 07 Agro for crop dusting (Ref. 4) ,the Groen Hawk 4 for security for the winter Olympics (Ref. 5), and the Auto-Gyro MTO Sport for police surveillance (Ref. 6), though these projects are scarce and often not widely adopted. The biggest reason is their reputation of being unsafe because of much higher fatality rates as compared to other type of aircraft (Ref. 7). That is somewhat ironic because autogyros are immune to engine failure as they can simply continue autorotation and land find a landing spot easily. However, the pitch instability (Ref. 8) combined with historically unsafe and unregulated practices in design, training, manufacturing and maintenance have caused this bad reputation.

Fortunately, the perception is slowly changing and increase in reliability and use of modern avionics and equipment has increased interest in autogyros (Ref. 9). These improvements could indicate that a modern autogyro design may be able to assist providing similar, though lesser, capabilities to a standard helicopter at a small fraction of the price and operating cost. This would allow air ambulance services to reserve their helicopters for the missions where the helicopter capability is truly needed, opening up availability for the network and reducing overall operating costs by reducing unnecessary use of the more expensive helicopters. The key aim of this work is to identify whether the use of autogyros for a subset of HEMS missions is technically feasible and therefore would allow for the HEMS to run at lower cost and/or higher availability. The key highlights will be: i) the missions in current HEMS that could potentially be performed by autogyro; and ii) the percentage of these missions to understand the feasibility.

METHOD

Autogyro have lesser capabilities in every performance aspect as compared to helicopters, therefore the assessment of autogyro in medical services requires a careful investigation to determine the sweet spot, where they can operate the best in. This requires a trade-off on performance assessment, which can be done using statistical and performance calculations; analysing HEMS missions; and defining HEMS requirements.

To realistically determine the missions that could be performed by autogyros, it is crucial to closely examine their operations, gathering key information such as landing sites, types of trauma, and the critical care provided. For this purpose, several HEMS charities in the UK were selected, which are the Great Western Air Ambulance (GWAA) and Wiltshire and Bath Air Ambulance (WBAA) and Warwickshire, Northamptonshire and Derbyshire, Leicestershire and Rutland Air Ambulance (WNDLR). All these three are selected as they provide a good mix of city and rural service and provide data for their services. The data allow to understand the HEMS missions, and make trade-off decisions such as number of crew, type of missions (patient transport or at-the-scene support), kit, and mission range.

Moreover, existing autogyro data on landing and take-off distances, maximum take-off weight (MTOW) and empty wight fraction (EWF), cruise speed and range are considered (Table 1) to check if the statistical estimates could be provided with current technology. For this purpose payload, fuel and MTOW are calculated using statistical analysis to ensure that the results are realistic. For landing sites, online maps are used to determine landing sites that could stay within existing autogyro capabilities. Once all data are gathered a replacement ratio is calculated, which refers to the amount of missions that could possibly be performed using an autogyro.

ANALYSIS AND RESULTS

Patient Transportation

While the general expectation from a HEMS is to transport the patient to a hospital, this is not the norm. In fact, the data from medical air ambulance missions tells a different story. Using data from the WNDLR air ambulance (Ref. 19) missions, the percentage of patients transported to hospital by air or by land are identified. From this data, it was found that only 24% of patients were transported to hospital by air as visualised in Fig. 1. This result is in favour of the use of autogyro in EMS as helipads on top of hospitals are not suitable for an autogyro due to the incredibly short landing and take-off distances required to land there. Additionally, the size increase required for patient transportation would require larger autogyro as they would have to transport additional life support equipment together with the weight of an additional person. As such 76% of missions are still available to an autogyro functioning as a medical air ambulance in instances, where land based patient transportation is feasible, the patient transportation is not considered in a feasible autogyro that could support HEMS. This means that about the quarter of all missions that requires air transport should be conducted by helicopters only, whereas autogyros can only be utilised in other cases, where appropriate.

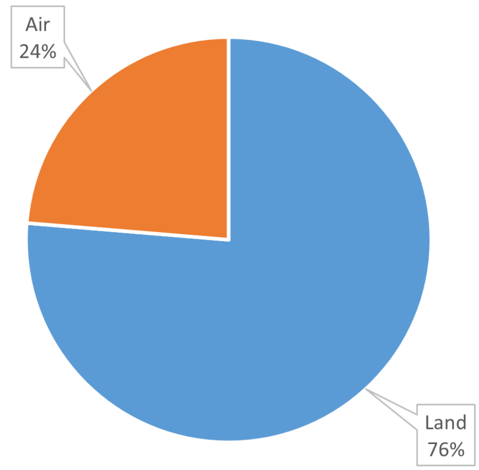

Figure 1. Percentage of hospital transfers vs on-site medical care with land vehicle transfer after HEMS missions (Ref. 19).

Number of Crew

An important factor is the crew weight as this directly determines most of the payload weight and hence autogyro performance. A typical helicopter used in medical services has 4 seats consisting of pilot, paramedic 1, paramedic 2/doctor, and 1 other individual of various roles. However, when the HEMS missions are analysed, the majority of missions do not use all 4 seats. As presented in Fig. 2 obtained from (Ref. 20), in 91% of the HEMS missions, only 3 members of crew are present, the pilot and 2 paramedics or 1 paramedic and 1 doctor. 8% of the time there are 4 members of crew present, often with 1 being a trainee, though trainees are often present as 2nd paramedics in 3 crew missions so this is variable. 1% of the time there are only 2 crew members present with a pilot and 1 paramedic. Therefore, 3 crew is the optimal number of crew for an autogyro. 2 crew would significantly limit the autogyro service and 4 crews would not easily justify the added mass as it only covers 8% of the missions. Assuming 90 kg weight per crew as per NHS guidance (Ref. 21) and an additional 10 kg assumed for personal gear (helmets, boots etc.), 300 kg total crew weight is expected.

Table 1. Autogyro Data obtained through open sources: MTOW (Maximum Take-Off Weight, Empty Weight Fraction (EWF), Landing distance, Take-off distance, Cruise Speed, Range and Fuel Weight.

Aircraft Name & Reference	MTOW (kg)	EWF (%)	Take-off (m)	Landing (m)	Range (km)	Cruise Speed (km/h)	Fuel (kg)
Air & Space 18A (Ref. 10)	816	0.71	-	-	483	129	77
American Ranger 1 (Ref. 9)	571	0.55	61	9	750	177	45
Apollo AG1 (Ref. 11)	512	0.56	-	-	535	170	46
ArrowCopter AC20 (Ref. 12)	560	0.63	-	-	-	165	51
Artur Trendak Taifun (Ref. 13)	600	0.62	100	5	850	175	64
Artur Trendak Taurus (Ref. 13)	600	0.58	150	15	450	140	57
Artur Trendak Tercel (Ref. 13)	560	0.63	85	5	800	160	57
Autogyro Calidus (Ref. 11)	560	0.54	110	18.3	600	185	71
Autogyro Cavalon (Ref. 11)	600	0.54	110	18.3	600	185	71
Autogyro MTO Sport (Ref. 11)	560	0.52	110	18.3	550	185	68
Aviomania Exodus (Ref. 14)	601	0.47	-	-	-	160	71
Aviomania Genesis G1Sa (Ref. 11)	350	0.48	-	-	292	130	26
Aviomania Genesis G2Sa (Ref. 11)	560	0.43	-	-	-	150	50
Brako GT (Ref. 9)	550	0.48	-	-	-	177	-
Brako Sprint (Ref. 9)	380	0.55	-	-	-	177	-
Brako Rad (Ref. 9)	550	0.50	-	-	-	167	-
Bensen B-8 (Ref. 10)	227	0.49	91	6	480	97	26
Celier Xenon iV (Ref. 11)	574	0.51	-	-	400	209	63
ELA 07 (Ref. 9)	450	0.56	-	-	400	140	53
ELA Eclipse (Ref. 9)	530	0.58	100	20	600	160	58
Fusioncopter (Ref. 15)	235	0.49	100	15	132	92	14
Groen Hawk 4 (Ref. 16)	1587	0.71	46	-	531	193	204
Magni M16 (Ref. 11)	500	0.53	70	31	480	150	52
Magni M22 (Ref. 11)	500	0.57	70	31	480	150	58
Magni M24 (Ref. 11)	500	0.57	74	31	480	150	58
Mcculloch Super J-2 (Ref. 10)	725	0.72	-	-	322	170	-
Niki Kallithea (Refs. 9, 10)	600	0.50	150	20	560	140	47
Niki Lightning (Ref. 9)	560	0.51	150	20	540	135	50
Pal V Liberty (Ref. 17)	910	0.73	180	30	500	140	71
RAF 2000 GTX (Ref. 10)	699	0.53	-	-	-	145	60
Sport Copter Vortex (Ref. 11)	345	0.55	20	6	273	120	40
Sport Copter Vortex M912 (Ref. 11)	445	0.59	15	6	386	177	50
Sport Copter II (Ref. 11)	771	0.57	60	6	482	177	92
Tango 2 (Ref. 9)	567	0.52	-	-	-	137	45
Titanium (Ref. 9)	576	0.47	-		-	161	65
Pegasus (Ref. 18)	900	0.59	0	0	160	610	-

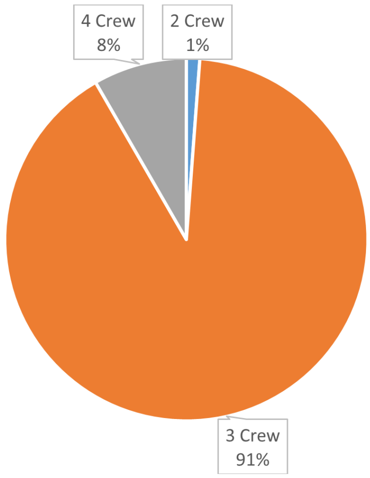

Figure 2. Mission count considering number of crew in Wiltshire, Somerset, and Bristol between 10/02/25 and 10/04/25 (Ref. 20).

Equipment

The East Anglican Air Ambulance lists the equipment carried by the crew for at-the-scene life support, for which weights can be found from manufacturer websites and technical documents (Ref. 22). Totalling up the mass of all equipment gives an equipment mass of $93.8kg$, as reported in Table 2. though in conversation with a medical air ambulance pilot it was suggested that the blood bag, oxygen tanks and ventilation unit were less critical for missions and could be left off in certain circumstances which leads to an equipment mass of $63.6kg$ though in either case this is almost an entire additional person in equipment mass. This same kit is carried by Critical Care Cars and therefore would have to be carried by an autogyro air ambulance and is a minimum requirement. If the patient is transferred by the autogyro, there needs to be more equipment on board to accommodate and support the patient and structural reinforcement could be needed as well, which is much heavier than the kit that supports patient only on the ground.

Table 2. Typical kit carried by HEMS for ons-ite life support and their weights (Ref. 22).

Kit	Weight (kg)
Immediate Care Bag	16.93
Critical Care Bag	14.32
Patient Monitor	8.97
CPR Machine (LUCAS)	12.84
Paediatric Bag	5.57
Blood Bag	13.75
Oxygen Tank	3.36×2
Ventilator	9.66
Fluid Suction Unit	3.18
Computer	1.82
Total Care Equipment Weight	93.8 kg

Figure 3. Map of the Counties served by Great Western Air Ambulance in the South-West UK.

Cruise Speed and Range

The GWAA is based at Almondsbury, Gloucestershire and serves Bristol, Wiltshire, Bath and North East Somerset and North Somerset, as presented in Fig. 3. Using a County Map and Google Maps measurement tool we can suggest a mission radius of 80 km. Air ambulance charities aim to be within the scene within 20 minutes (Ref. 23), which covers the time between take-off and landing. For 80 km mission range, this would require a significantly higher speed than the fastest identified autogyro, which has a cruise speed of 210 $\mathrm{km\,h^{-1}}$. Existing autogyro are all predominantly for personal use and therefore use widely available consumer engines which would limit their power output and therefore cruise speed. Additionally, as maximum cruise speed increases, rotor length or rotor rotation rate must decrease so as to avoid compressibility effects on the advancing side blades of the rotor, this limits the low speed performance of rotors designed for high speed use which would increase landing distances and may remove the benefits of the use of an autogyro compared to a fixed wing aircraft. As such a lower speed would be more reasonable for an autogyro.

If we consider a reasonable maximum mission distance of 80 km to cover the counties served by the GWAA from NPAS Almondsbury, then a distance of 64 km would cover 80% of the call-outs assuming even distribution of distances. This suggests a cruise speed of 192 km/h would be sufficient to reach 80% of call-outs in 20 minutes, which is in line with many other autogyro identified in Table 1.This therefore would require a cruise range of 128 km for flight to the incident and flight back. With an additional reserve of fuel for 30 minutes of flight at cruise power, the range needs to be 160 km.

Maximum Take-off Weight

With the number of crew and medical equipment now determined, the next step is calculating the MTOW (maximum take-off weight) of the HEMS autogyro, as this can help to understand its possible architecture and dimensions. The maximum take-off weight is the sum of the masses of payload (medical kit), crew, fuel including reserves and the empty vehicle, which can be written as:

$$MTOW = M_{PL} + M_C + M_F + M_{OWE}, \quad (1)$$

or using the fuel weight ($\frac{M_F}{MTOW}$) and empty weight ($\frac{M_E}{MTOW}$) fractions:

$$\begin{aligned} MTOW &= M_{PL} + M_C + \frac{M_F}{MTOW} MTOW + \frac{M_E}{MTOW} MTOW, \\ &= \frac{M_{PL} + M_C}{1 - \frac{M_F}{MTOW} - \frac{M_E}{MTOW}}. \end{aligned} \quad (2)$$

Above equation requires the fuel fraction and the empty weight fraction. These ideally requires completion of preliminary and detailed design stages, which is out of the scope of this work. Instead, Table 1 is used which lists many of the existing autogyros. While the HEMS autogyro is expected to carry a useful payload (3 crew and equipment in Table 2, near 400 kg), this amount is not significantly bigger than existing autogyros, therefore the estimates based on statistical data are expected to be realistic.

Starting from the empty weight fraction, the list reports values as low as 0.43 and as high as 0.73 with an average value of 0.54. It can also be observed that the EWF slightly increases with increasing payload mass. The trends suggests that $EWF = 0.6$ is a reasonable value for a 3 crew autogyro carrying an on-site help kit.

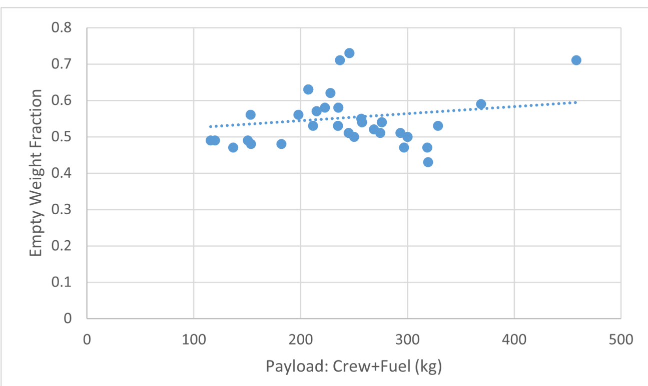

Figure 4. Empty Weight Fraction of existing autogyros.

The remaining term is the fuel weight or its ratio to the MTOW. To stay within the scope, this can be estimated statistically by finding the fuel weights of the existing autogyros, which range between 7% to 8%. However, the fuel weight also depends on the range and cruise speed and the HEMS autogyro is expected to have a shorter range than those listed. To solve this issue, the Breguet Range Equation is used which leads to the weight fraction:

$$1 - \frac{M_F}{M_{TOW}} = e^{-\frac{Rc}{VL/D}} \quad (3)$$

where R is range, V is the cruise speed, c is the specific fuel consumption and L/D is the lift to drag ratio. The above equation is used to scale the fuel fraction of the autogyro listed in Table 1, which ends up between 1.5% to 3.6% . To account for the high payload, fuel weight fraction was chosen as the maximum of this value added with a 10% safety margin, ending up 4% of the MTOW. The two fractions are inserted into Eq. 2, which results in:

$$MTOW = \frac{300 + 93.8}{1 - 0.04 - 0.6} = 1105 \text{ kg}, \quad (4)$$

with a fuel mass of 44 kg, which indicates that the MTOW is on the upper end of the listed autogyros.

Night Missions

A typical autogyro flight occurs during daylight hours due to their predominant use in sport and leisure aviation. Recently, however, some manufacturers have begun offering instrumentation that enables flight after sunset (Ref. 13). While such advancements may support operations in lower-risk scenarios, HEMS often require landings in unpredictable environments, where a clear visual of the landing site is essential. Helicopters can manage this due to their ability to hover, providing time to assess and safely execute a landing. Nevertheless, even some HEMS providers avoid night operations because of the heightened risk (Ref. 24). For autogyros, which lack the capacity to hover or land vertically, such conditions pose a significant challenge—particularly when urgent medical intervention is needed.

It is therefore necessary to exclude night-time missions when assessing the suitability of autogyros for HEMS. Reported figures vary: approximately 11% of HEMS missions in Switzerland occur at night (Ref. 25), compared to 27% in South-East England (Ref. 26), and 38% in the United States (Ref. 27), indicating substantial regional differences. A preliminary analysis was conducted using the WBBA mission log, comparing a winter month and a summer month to account for seasonal variation in mission timing. The data and resulting percentages, presented in Table 3, suggest that approximately 76% of missions occur during daylight—consistent with the figure reported for South-East England, a region comparable to the WBBA coverage area. Thus, for an initial estimate, we can assume that 76% of HEMS missions could potentially be served by autogyros, assuming they operate only during daylight.

Table 3. Day vs total operations.

Month	Daylight	Missions (Day/Total)	Percentage
JAN	8.25 hr	11/16	68.75 %
JUN	16.5 hr	34/55	78.18 %

Landing and Take-Off

Helicopters can land to confined spaces measured using D-value, where D refers to maximum overall dimension of the helicopter; typically measured as the distance from the most forward part of the spinning rotor to the tip of the tail. 2D,

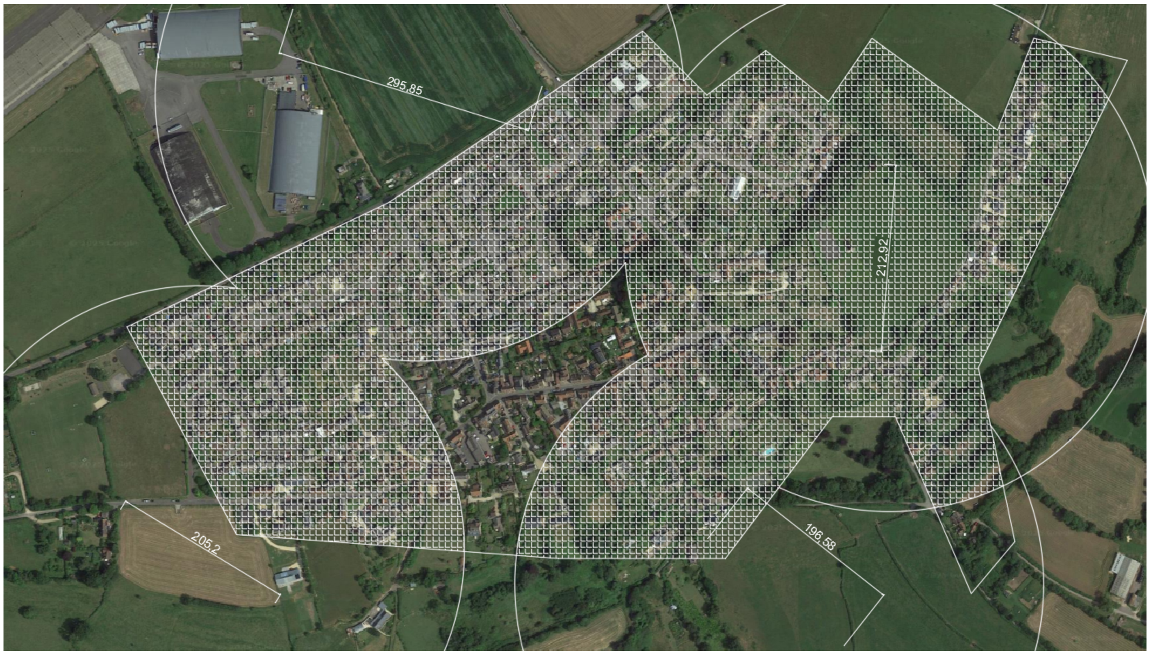

Figure 5. Autogyro service coverage at Colerne: 90.9% **of total area.**

Figure 6. Autogyro service coverage at Peasedown St John: 73.1% **of total area.**

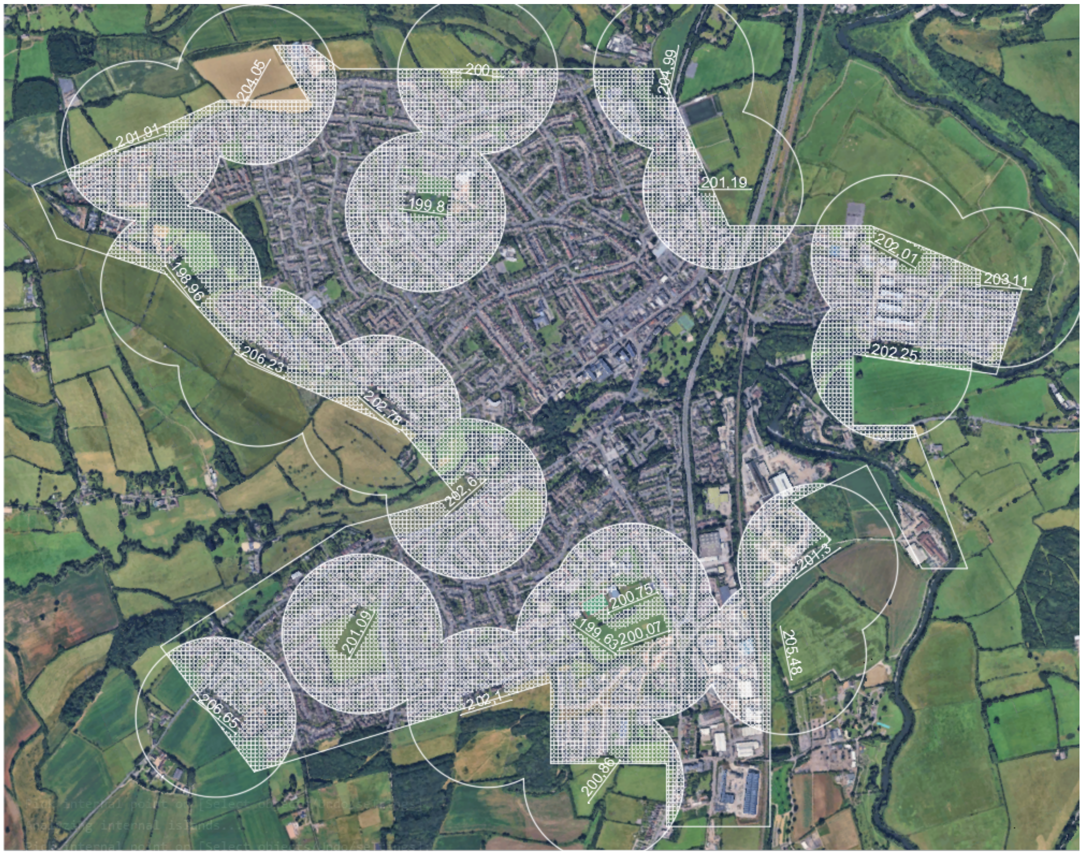

Figure 7. Autogyro service coverage at Keynsham: 54.2% **of total area.**

Figure 8. Autogyro service coverage at Bath: 31.1% **of total area.**

or double the maximum overall dimension, is generally expected as a rule of thumb for proper landing zones. Typical values range from 20 – 40 m for the conventional main rotor tail rotor configuration. And additionally, take-off and landing can be performed using the same area, which is a clear advantage of helicopters in medical services. To assess autogyro capabilities for HEMS use, landing and take-off capabilities should better be understood. As such there is concern that the autogyro would not be able to land close enough to a location in order to attend missions.

Autogyros can not match helicopter capabilities in terms of vertical landing and take-off. While near vertical landings are possible, take-off still requires a ground roll. This can be clearly observed in Table 1, which presents an order of magnitude longer take-off distance as compared to their landing performance. Therefore the limiting criteria is the take-off performance, which needs to be addressed. Going back to the take-off data given in Table 1, values range between 61 to 180 m, with some exceptions of jump take-off claims (0 m). Excluding the special case of jump take-off, the data shows that autogyros can practically take-off under 200 m including clearing obstacles. When looked around towns, villages and cities, such areas actually exist in the forms of sport (football, cricket etc) pitches, school grounds, commons or relatively smooth (not ploughed) fields. However, these areas gets bigger towards the peripheries of settlements and most likely the long enough ones are limited to the boundaries of settlements. This limits the medical service performed by autogyros to the boundaries of urban and rural areas. Therefore, finding such zones and determining a practical service area is critical to assess the percentage of missions that could be done with an autogyro.

For the purposes of finding suitable landing zones a stretch of 200m of land with no trees, fences, or other obstructions, or dramatic changes in ground gradient, would be considered suitable. From these landing strips a mission radius of 300m is used as at a brisk walk of 6 km/h this distance would be covered in 3 minutes which would not substantially add to mission time. This is referred to as the autogyro service area in this work. Using these service areas and comparing them to an irregular polygon drawn as the outline boundary of a village, town, or city it is possible to estimate the effective coverage that could be offered by an autogyro mission. In this work, 4 settlements ranging from village to city are selected to manually find such zones and estimate a autogyro medical service coverage.

The first settlement is Colerne, a village in Wiltshire with a population of 2700 (Fig 5). As Colerne is a small village with most of the area within 300 metres of the outer edge of the city the autogyro crew would not have significant difficulty covering large parts of the village and the autogyro HEMS coverage is estimated as 90.9%. The 2nd settlement is a larger one, representing a large village or a small town. The village of Peasedown St John is within the Somerset area with a population of 6446 (Fig 6). As Peasedown St John is still a village, most of the area can be covered by landing strips in the outskirts of the village, however buildings towards the heart of the village

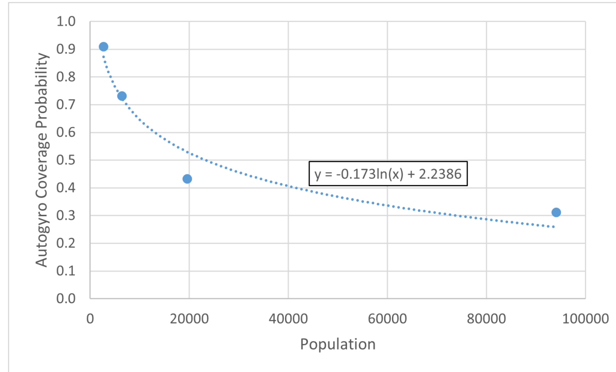

Figure 9. Probability of an available zone for an autogyro based on Table 4.

start to be outside what can reasonably be covered by an autogyro as it would require considerable ground to be covered by a paramedic on foot. The 3rd place is Keynsham, a town near Bristol with a population of 19603 (Fig 7). Due to the increased size as compared to villages/small towns, less of the village is close to the outskirts causing significant sections of it to be outside the mission area, as there are almost no parks or open spaces big enough at the centre. This reduces the coverage to 54.2%, which is less than that of the village but still a substantial number that can justify the use of autogyro. The final settlement is Bath (Fig. 8), a city in Somerset with a population of 94092. Bath being a city larger then mentioned settlements causes areas with less open spaces which therefore prevents landing zones from being placed near the centre of the city causing significant sections of the city to be outside of the area that could be covered by an autogyro. These findings are summarised in Table 4.

Table 4. Autogyro service coverage in sample settlements.

Settlement	Population	Coverage (%)
Colerne	2700	90.9
Peasedown St John	6446	73.1
Keynsham	19603	54.2
Bath	94092	31.1

These 4 settlements now can be used to estimate the percentage of landing zones available to autogyros. As the populations are different, the probability to be called for an event also changes with population. Therefore, it is not possible to simply average the four settlements coverage. Instead, first an equation is obtained using the 4 population zones and a trendline is fitted for different populations, as presented in Fig. 9. The probability of serving an area with an autogyro ($P_{zones,S}$) is best captured by a logarithmic function which is found as:

$$P_{zones,S} = 2.23 - 0.17\log(N_{S_i}) \quad (5)$$

where N_{S_i} is the population of that settlement.

Second, data is collected from (Ref. 20) based on location and number of events served within a month as presented in Table 5, which gives the probability of an event happening at

Table 5. Event probability and autogyro service coverage in sampled settlements.

# of Events	Population	Event Probability	Landing Coverage	Local Coverage
11	233400	0.196	0.101	0.020
1	5236	0.018	0.758	0.014
1	2252	0.018	0.904	0.016
1	5969	0.018	0.735	0.013
4	36548	0.071	0.422	0.030
1	13396	0.018	0.596	0.011
1	2415	0.018	0.892	0.016
2	17461	0.036	0.550	0.020
1	558	0.018	1.145	0.020
2	15980	0.036	0.565	0.020
7	41280	0.125	0.401	0.050
1	2223	0.018	0.906	0.016
1	11968	0.018	0.615	0.011
1	3578	0.018	0.824	0.015
1	2461	0.018	0.889	0.016
2	8932	0.036	0.666	0.024
1	10810	0.018	0.633	0.011
1	82418	0.018	0.281	0.005
1	12415	0.018	0.609	0.011
1	6149	0.018	0.730	0.013
1	1658	0.018	0.957	0.017
2	94092	0.036	0.259	0.009
1	10500	0.018	0.638	0.011
1	1883	0.018	0.935	0.017
3	46000	0.054	0.382	0.020
2	16414	0.036	0.560	0.020
1	1000	0.018	1.000	0.018
2	18173	0.036	0.543	0.019
1	77	0.018	1.000	0.018
			Total:	0.502

a specified settlement ($P_{event,S}$, 3rd column). The populations of these locations are inserted into Eq. 5 to estimate the landing coverage at different settlements ($P_{zones,S}$), which is given in the 4th column and the total probability of an emergency event is served by an autogyro at that location is given by the multiplication of the two probabilities:

$$P_{landing,S_i} = P_{event,S_i} P_{zones,S_i} \tag{6}$$

which is provided in the 5th column. The total probability which refers to an autogyro can respond to an event at the given area is given as the sum of these probabilities:

$$P_{landing} = \sum_i P_{landing,S_i} = 0.50 \text{ or } 50\% \tag{7}$$

meaning that half of the helicopter missions can be done using an autogyro based on event distribution and typical landing sites.

Helicopter Replacement Ratio

After determining the realistic characteristics of a HEMS autogyro, the final analysis is finding the percentage of missions that autogyro can replace helicopters ($P_{replacement}$). The critical factors are range, number of crew, patient transfer and landing zones. Therefore multiplication of all parameters could lead to an estimate of the replacement ratio:

$$P_{replacement} = P_{range} P_{transfer} P_{crew} P_{day} P_{landing} \tag{8}$$

where:

- P_{range} is the percentage of missions that can be done using autogyro based on reduced range, which is set to 80% based on typical cruise speed;
- $P_{transfer}$ is the percentage of missions that can be done using autogyro based on at-the-scene support only instead of transfer to hospital by air, which was found to be 76% based on annual HEMS analysis;
- P_{crew} is the percentage of missions that can be done using autogyro based on 3 crew instead of transfer to hospital, which was found to be 92% based on annual HEMS analysis that excludes 4 crew missions;
- $P_{landing}$ is the percentage of missions that can be done using autogyro based on available landing zones based on 200 m open flat surfaces and probability of events with population and it was estimated to be 0.50;
- P_{day} is the percentage of missions performed under daylight and is estimated to be 0.76 based on the time recorded in mission data;

All the above estimates iare based on the HEMS analysis presented above. Now, the total replacement probability can be calculated using Eq. 8:

$$\begin{aligned} P_{replacement} &= P_{range} P_{transfer} P_{crew} P_{day} P_{landing} \\ &= 0.80 \times 0.76 \times 0.92 \times 0.76 \times 0.50 = 0.21 \end{aligned} \tag{9}$$

which indicates that based on the preliminary analysis, 21% of HEMS missions could possible be served using an autogyro.

DISCUSSIONS

Analysis provided critical information to understand the potential role of autogyros in HEMS services. Table 6 summarises the critical specs determined after analysis. Based on these findings, following discussions can be made for an autogyro that can provide service in HEMS.

As response time is critical, range is limited to 160 km or a 80 km mission radius. The analysis considered a typical cruise speed, although slightly higher than the average and range is determined based on response time and cruise speed. Increasing the range requires a faster autogyro. Faster autogyros are possible within existing technology with more power but there is still a limit due to rotor aero mechanics. Slowed rotor+wing combinations (Ref. 28) can solve some of these problems, but such concepts are experimental therefore excluded from analysis.

Table 6. Summary of Emergency Medical Service requirements for an autogyro.

Requirement	Value	Unit
Patient Transport	No	[]
Number of Crew	3	[]
Weight of Crew	300	kg
Weight of Equipment	93.8	kg
Maximum Take-off Weight	1105	kg
Fuel Weight	44	kg
Range	160	km
Cruise Speed	192	km/h
Estimated Helicopter Replacement	21.0	%

In the ideal case, 4 members of crew would be required. However, autogyros have less payload carrying capability as compared to helicopters, therefore a 3 crew autogyro would be the feasible option that could save around 100 kg while providing crew for most of the cases. Reducing the crew to 2 is not useful and would only be for a very small fraction of missions. Therefore, an ideal autogyro that could serve within HEMS should be capable of carry two paramedic/doctors in addition to its pilot, therefore total of 3 crew, leading to approximately 300 kg.

Transferring patient to hospital would add substantial weight for on-board life support and large space to accommodate the patient. Additionally, very few of the hospitals have a runway or similar strip that an autogyro can take off and most of the missions do not involve patient transfer, which is rather done using ground care vehicles. Adding patient transfer would lead to a more complex and heavy autogyro (VTOL capabilities, additional medical equipment on board) which reduces the benefit of using an autogyro for reduced cost in the first place.

Around 400 kg payload should be considered, comprising of 3 equipped crew and kit to support/stabilise patient at the scene. The bigger payload can be compensated partially with the fuel weight. The useful payload (crew+equipment+fuel), which is estimated to be 440 kg.This leads to a maximum take-off weight is expected to be about 1105 kg, leading to a vehicle on the very heavy side of the spectrum. This can be reduced using composite materials but this would likely to increase the price. However, there are proven examples (Pal V Liberty and Groen Hawk 4), that is close enough to suggest that the existing technology can provide this payload capacity.

Landing is not critical as autogyros demonstrate almost vertical landing capability but take-off is the limiting factor. The maximum take-off distance can be expected as a guide, therefore smooth areas under 200 m can be possible landing zones within the existing technology, which can be shortened if needed using powerful engines. Jump take-off needs a brief mention here though, as it can give VTOL capability to autogyros. This requires a collective pitch and pre-rotate system that accelerates the rotor to approximately 50% higher than that required during flight. While a conventional take-off is performed outside the dead man's curve on the height-velocity (H-V) diagram, a jump take-off must be carried out within the region that is typically restricted for conventional take-off. However, as mentioned in (Ref. 29), if a safe landing is still possible in the event of engine failure, a jump take-off can be considered feasible. Although this capability could be a valuable feature for an autogyro-based medical service and promoted in recent designs (Ref. 18), it is not considered in this study due to the need for further research and development to smooth the process (see for example (Ref. 30)).

The coverage is limited by landing zone availability and reduces with the size of the settlement as summarised in Table 4. This is an expected result but the numbers can justify the use of autogyro in semi-urban or rural areas as the coverage can be as high as 90%. Additionally some service could still be provided to the boundaries of cities, which can be still at about 30%.

When considered together with all the trade-offs, a helicopter replacement ratio of 21% is estimated. Therefore, autogyros can support an important fraction of HEMS missions. Nevertheless, their economical viability needs further assessment and possibly on base-by-case basis, as the replacement is partial and can be affected by local variables.

CONCLUSIONS

Above discussions concludes that a HEMS autogyro is technically feasible with current technology if a trade-off is made between the payload and HEMS missions and using autogyro in a supplementary role to helicopters to reduce cost. The most important results of the paper should are summarised as follows:

1. Trade-offs on crew number, patient transport, range and crusie speed are necessary to design a medical autogyro which can replace some of the helicopter missions.

2. Based on HEMS mission investigation and statistical analysis, it was estimated that 28% of the helicopter missions can be replaced with an autogyro. This number could change but a substantial increase requires new technologies such as slowed rotor and jump take-off.

3. The medical autogyro is estimated to have a MTOW of 1105 kg, which is heavy but still lower than Groen Hawk 4, indicating that a design based on the mentioned trade-offs can lead to a feasible medical autogyro.

4. Additional work should be done to support the findings, which include: i) design optimisation for sizing the rotor and airframe; ii) applying the analysis to different HEMS to verify findings; iii) using advanced simulations to inform the design changes required in existing. There is also a need to address the feasibility of new technologies such as jump take-off and slowed rotor, on a medical autogyro.

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