Clinical Standard Operating Procedure (SOP)

NON-INVASIVE, CONTINUOUS POSITIVE AIRWAY

SETTING	Service-wide
FOR STAFF	All staff
PATIENTS	All patients requiring high flow nasal therapy, NIV or CPAP

Introduction

On occasion, patients receiving non-invasive ventilation (NIV), continuous positive airway pressure (CPAP) or high-flow nasal oxygen (HFNO) therapy may be referred for transfer by Retrieve. This document outlines the practical considerations involved; in some cases, NIV/CPAP/HFNO transfers will not be feasible and this document outlines the process of determining which transfers can or cannot be safely accepted.

In the setting of COVID-19, Retrieve is unable to move any patients who are continuously dependent on this therapy unless they are confirmed to be negative on contemporaneous testing.

Oxygen requirements

Estimation of oxygen requirements is challenging – it requires consideration of multiple variables which can vary over a significant range.

The usual principles of calculating oxygen requirements based on assumption of FiO_2 = 1.0 and doubling the transfer duration should be applied. Calculating at FiO_2 = 1.0 provides for a scenario where the patient's clinical requirements increase to that level for some or all of the transfer. Doubling the duration provides for delays or other unexpected contingencies. In comparison to invasive ventilation, gas flows are very high and can be dramatically affected by additional factors and considerations:

- Non-invasive ventilation leak (all dependent on pressures required for therapy):
  - Intentional leak – required for CO_2 clearance
  - Unintentional leak – dependent on patient interface and anatomy + degree of aerophagia

A moderate degree of unintentional leak is around 20LPM[1]. The Hamilton T1 ventilator is capable of compensating for a total leak (intentional + unintentional) of 85LPM. In addition, a further 20% in gas consumption should be added to account for the compliance of the circuit and patient interface.

An approximate calculation for oxygen consumption is therefore:

Volume = ((FiO_2 x MV x 1.2) + 20) x duration of transfer in minutes) x 2)

As an example, a patient with a minute volume of 10L requiring transfer from North Devon District Hospital to the Royal Devon and Exeter Hospital (60 minutes) would have a gas consumption of 3,840L. This equates to 1 x ZX plus 2 x CD cylinders.

High flow nasal oxygen

For HFNO, the calculation is based only on duration and flow:

Volume = (FiO_2 x Flow) x duration of transfer in minutes x 2

For the same journey on HFNO at 50LPM this would require 6,000L which equates to 2 x ZX cylinders.

Reserves and onward planning

The examples given above use nearly half the available cylinder oxygen carried on Retrieve vehicles, or more. If these transfers are to be considered, it must be confirmed that all cylinders on the vehicle are full prior to departure. When planning whether to accept these referrals, reasonable consideration should be given to the potential need to undertake a follow-on referral for a time-critical patient immediately afterwards. Appendix 1 demonstrates typical isochrone distances from each hospital to illustrate the distance which can be travelled with the oxygen available on the vehicle. Appendix 2 tabulates feasible destination hospitals for each referring hospital in the South West.

Note that additional oxygen should only be carried on the vehicle when it can be properly stored and secured. Any cylinders of size E, or greater, should only be carried when secured to a purpose-constructed mount; cylinders must not in any circumstances be laid loose on the vehicle floor or on the patient.

Currently Retrieve vehicles carry 8,600L when fully stocked: 2 x ZX (3,040L) and 4 x CD (640L) in the vehicle, and a further 1 x CD plus 1 x E (680L) on the trolley. Due to Retrieve's contract with Bristol Ambulance, if replacement cylinders are required, swaps must be made at a Bristol Ambulance base (Bristol or Exeter) or Retrieve base.

With those caveats considered, it would be reasonable to plan to use >50% of the vehicle stocks to facilitate the NIV transfer, thus leaving supplies for an onward referral e.g., using 5,580L of 8,600L provided that careful attention is paid to an accurate oxygen calculation for a follow-on referral. As described above, only properly secured cylinders can be carried. Extra, unsecured CD cylinders cannot be collected to compensate for empty ZX cylinders, just as they cannot be carried unsecured to provide extra range for long-distance NIV transfers in the first place.

Equipment for therapy delivery

The Hamilton T1 ventilator is capable of delivering NIV, facial CPAP and HFNO with appropriate consumables.

For use in NIV or facial CPAP the Hamilton T1 ventilator would require a dual limb, humidified breathing circuit with reservoir and integrated heating and temperature control, an expiratory filter and **non-vented mask**. All of these consumables are available in the NIV/HFNOT bag on the ambulance. Unless you can be certain the patient's mask is non-vented and compatible, new consumables should be used. Masks are available in small, medium, large and extra-large.

For HFNO the same consumables are required, with a High Flow Therapy Nasal Cannula instead of a non-vented face mask. For patients requiring HFNO via a tracheostomy, an OptiFlow™ Direct Connector is supplied in the equipment bag.

In the set-up of these circuits an HME filter must be used (Appendix 3). This should be placed after the flow sensor (blue connector) and proximal to the patient.

The H900 Humidifiers are intended to be used for any patient requiring invasive or non-invasive ventilation, where dry humidification is felt to be inappropriate. For Retrieve's patient group this

includes all patients transferred with NIV or HFNO. Any other patient may be considered appropriate including tracheostomised patients. It can take up to 30 minutes for the device to reach temperature.

The H900 requires a power source otherwise it will only run off the residual heat plate. The default mode is set to invasive ventilation, this must be changed for any patient receiving non-invasive ventilation. The humidifier will always default to auto control settings. These can be adjusted but that will will automatically switch the device to manual mode. Auto mode can be re-enabled at any time.

The water chamber should only be filled with designated water for inhalation, available in the equipment bag. Do not overfill the chamber, as this will lead to water level swings on sharp turns and heavy braking causing the water level alarm to sound. This can be managed via the control panel. The H900 is not licenced for use in transfer.

The H900 should be plugged into the ambulance power sockets directly, rather than the multi-socket adapter on the trolley.

Problem solving

Appendices 4-5 show common alarm settings and associated steps to resolve them.

Infection control considerations

Delivery of NIV or HFNO for COVID-19 positive, or suspected-positive patients represents a significant hazard to Retrieve staff for the following reasons:

- Significant aerosol generation
- Enclosed space in the ambulance
- Extreme proximity of staff to the patient's airway (approximately 1 metre)
- Absence of managed air changes in the ambulance and non-negative pressure environment in the ambulance

Patients may therefore only be accepted for NIV/CPAP/HFNO transfer provided:

- They are otherwise within the scope of work of Retrieve
- They have a confirmed negative COVID-19 PCR test within the past 24 hours
- Do not require a volume of oxygen greater than that which can be safely carried in a Retrieve vehicle (in addition to re-deployment contingency supply for an intubated patient)
- The case satisfies a reasonable view on their predicted clinical course (see below).

Clinical decision-making

Retrieve is, first and foremost, a transfer and transfer-coordination service. A Duty Consultant from Retrieve will always be involved in the referral process and this offers the opportunity for consultant-level collaboration. Not all Retrieve Duty Consultants are Intensive Care Medicine specialists but, where possible, all will contribute to decision-making to support the referring team in their management of the patient. In the case of respiratory failure, patients requiring NIV/CPAP or HFNO, the Retrieve team have crucial transfer-related input to offer, as described elsewhere in this document. Ceilings of treatment remain the final responsibility of the referring consultant.

For a patient where NIV/CPAP/HFNO is their ceiling of treatment, due consideration must be given to the existing support requirements. If a patient is already on moderate- or high-levels of support, it may not be appropriate to transfer them as deterioration without recourse to escalation could lead to death during transfer. All cases are individual – distance of transfer and rate of deterioration

should also be considered, as well as reason for transfer e.g. moving a patient with heart failure requiring primary PCI may well be appropriate even where CPAP is their ceiling of care.

For patients where NIV/CPAP/HFNO is not their ceiling of treatment, the safest position is to intubate the patient for transfer if they have even moderate support requirements. En-route induction of anaesthesia and intubation is a high-risk undertaking and should not be a routine contingency. If, at the time of referral, intubation is deemed overly proactive on the basis that time may allow improvement and avoidance of intubation then the default position should be to defer the transfer decision until the need, or not, for intubation is more clear-cut.

Referral of patients in respiratory failure for trial and transfer on NIV/HFNO/CPAP falls outside the scope of Retrieve; the service cannot respond to calls to arrive and initiate these therapies.

COVID-19 patients receiving NIV/CPAP/HFNO

As previously stated, the logistical complexities of HFNO/NIV/CPAP transfers, when coupled with the risk to staff of acquired infection in the setting of COVID-19 mean patients infected with the virus cannot be transported by Retrieve while receiving this level of therapy.

All patients on these therapies can be classified as either fully dependent or partly-dependent on continuous treatment. As discussed in the setting of non-COVID-19 patients above, fully-dependent patients have a high clinical risk of deterioration and an intubated transfer, or no transfer at that time, should be the default. This also applies to COVID-19, fully-dependent patients.

For patients who are not fully-dependent, there is the potential to be able to transfer them, if they can tolerate a trial period on non-rebreathe mask oxygen for a period at least equal to the **end-to-end transfer time (not the on-the-road time).** This should be conducted in a semi-recumbent position to simulate the typical position during transfer. The trial should be conducted sufficiently in advance to allow a reasonable period (30-60 minutes) back on therapy, to re-recruit and re-optimise, prior to transfer. The Retrieve team undertaking such a transfer must liaise closely with the receiving hospital to ensure that the patient can immediately recommence therapy upon arrival.

Document Governance

REFERENCES	• Ueno Y, Nakanishi N, Oto J et al. A Bench Study of the Effects of Leak on Ventilator Performance During Noninvasive Ventilation. Respiratory Care, 2011, 56 (11) 1758-1764 • University College London Ventura CPAP Mark II device, Healthy Volunteers testing [Unpublished data] • https://www.youtube.com/watch?v=W-_dCvlUFs8&t=3s • https://www.hamilton-medical.com/en_GB/Products/HAMILTON-H900.html?gclid=CjwKCAjw0N6hBhAUEiwAXab-TYObfqAo1JkQkJOO_5M9UZ87amb8eIe9cTVfCvW_uVPBSntDjX5WrBoCutkQAvD_BwE • https://www.hamilton-medical.com/en_GB/Resource-center.html?ventilator=1499a5be-d3a5-4e57-af1a-b1226726af89&category=736b1b51-b3d2-4048-a64f-9bc268167da2&tab=d7dd4b8e-1047-4c29-a404-da2b41f2fa29&resource-lang=en&resource-detail-type=document&resource-detail-id=454d12a0-2dbf-4851-962e-585e02b0079e
RELATED DOCUMENTS AND PAGES	Oxygen calculation SOP
AUTHORISING BODY	
SAFETY	Oxygen calculation is a key part of transfer safety. This SOP describes the challenges that face the safe transfer of patients requiring NIV/HFNO, particularly in keeping the Retrieve team safe.
QUERIES AND CONTACT	Retrieve Leadership Team

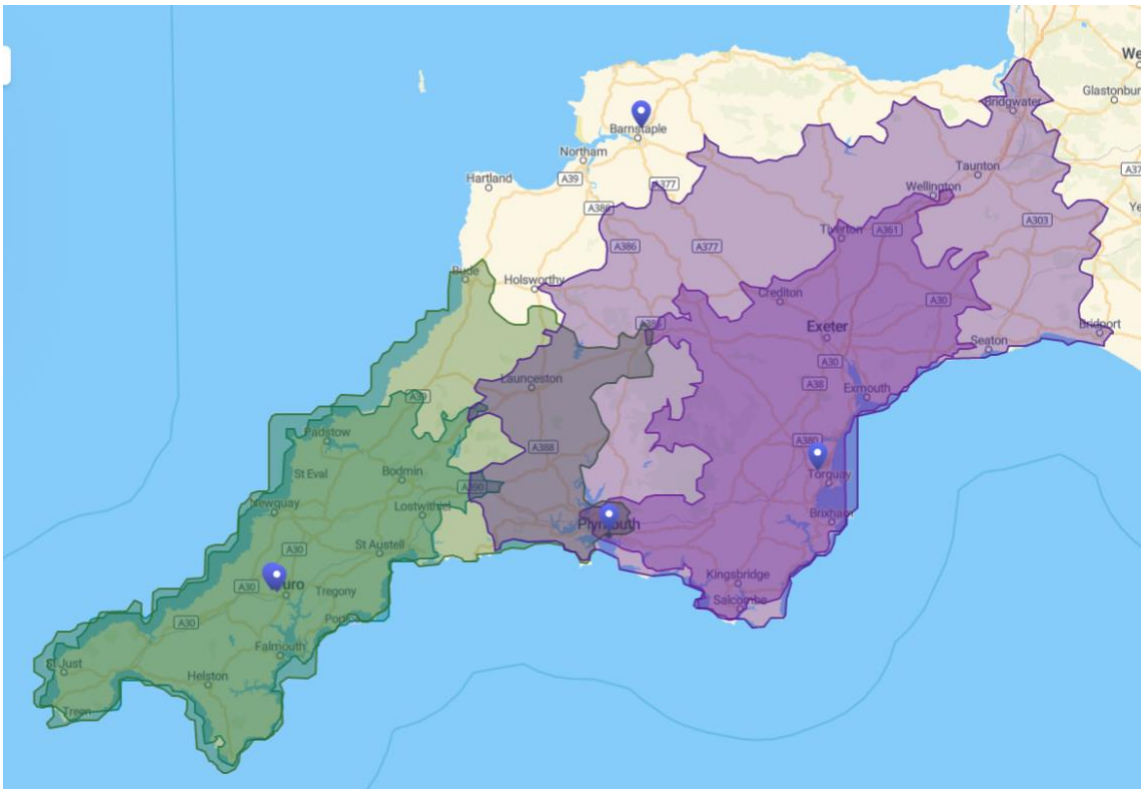
Appendix 1 – NIV/CPAP/HFNO distance from referring hospitals

The isochrone maps below illustrate the maximum distance of transfer which can be accomplished for a NIV/CPAP/HFNO transfer. The calculations are based on:

- FiO_2 1.0
- HFNO flow of 50LPM
- NIV patient with MV 10LPM, 20LPM leak, 20% uplift for circuit compliance

The calculations include the duration-doubling contingency i.e. the illustrated 60-minute isochrone is for an oxygen calculation based on a requirement for 120 minutes. It assumes that 2/3 of the vehicle oxygen (5,580L of 8,600L) can be utilised, thus reserving 3,020L for a follow-on referral.

- For NIV/CPAP: 78 minutes (simplified to 80-minute isochrone)
- For HFNO: 55 minutes



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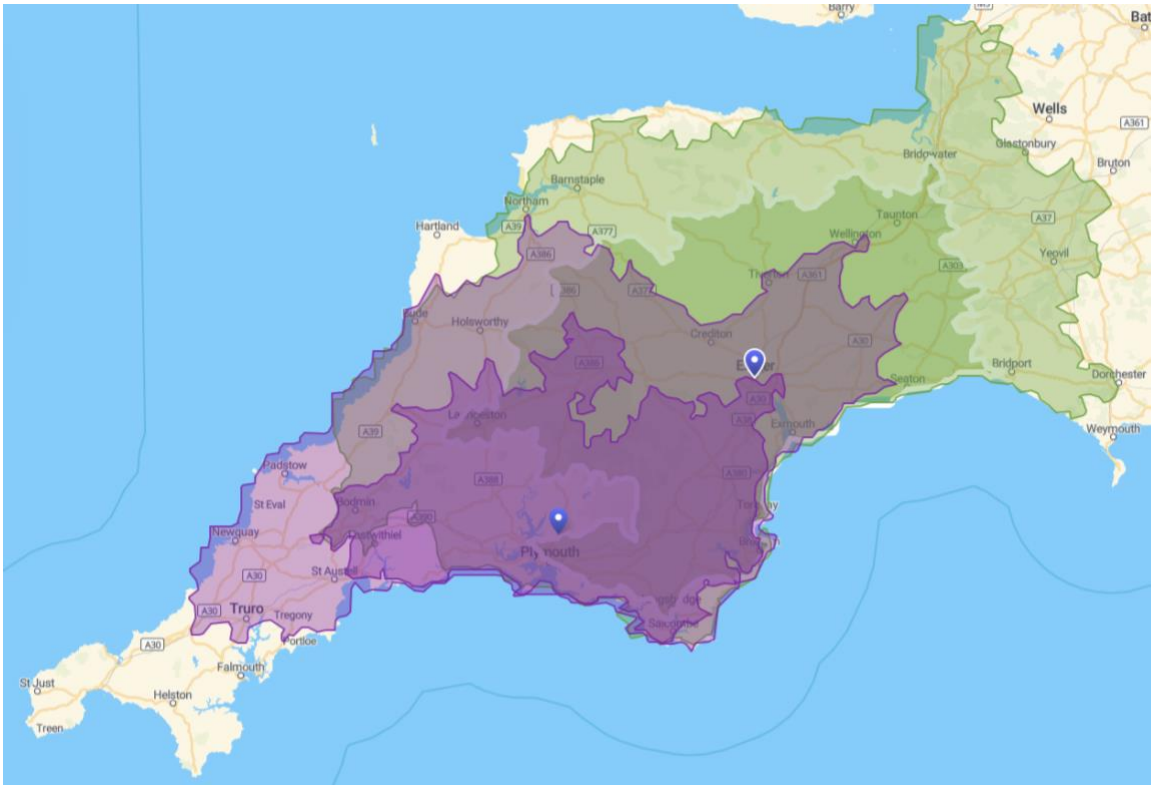
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Weymouth
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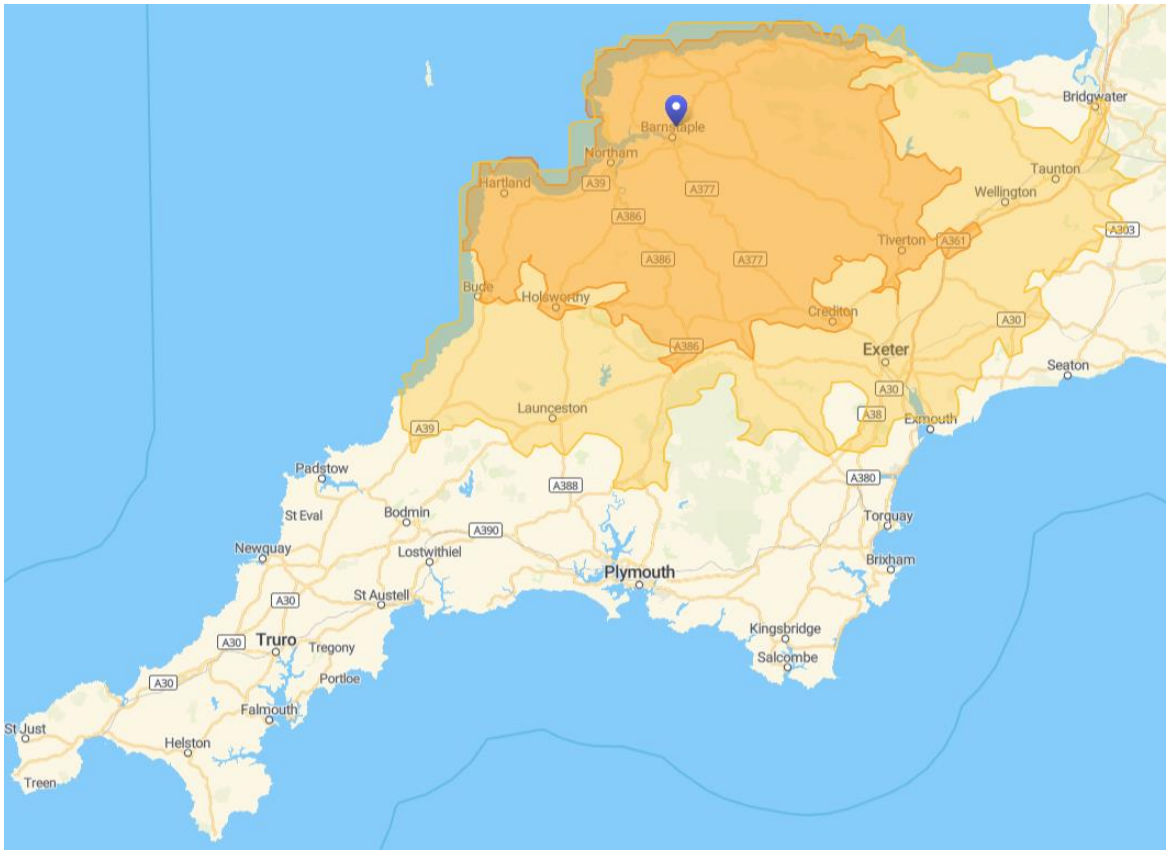
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Torquay
St Eval
Bodmin
Newquay
Lostwithiel
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Salcombe
Portloe
Falmouth
St Just
Helston
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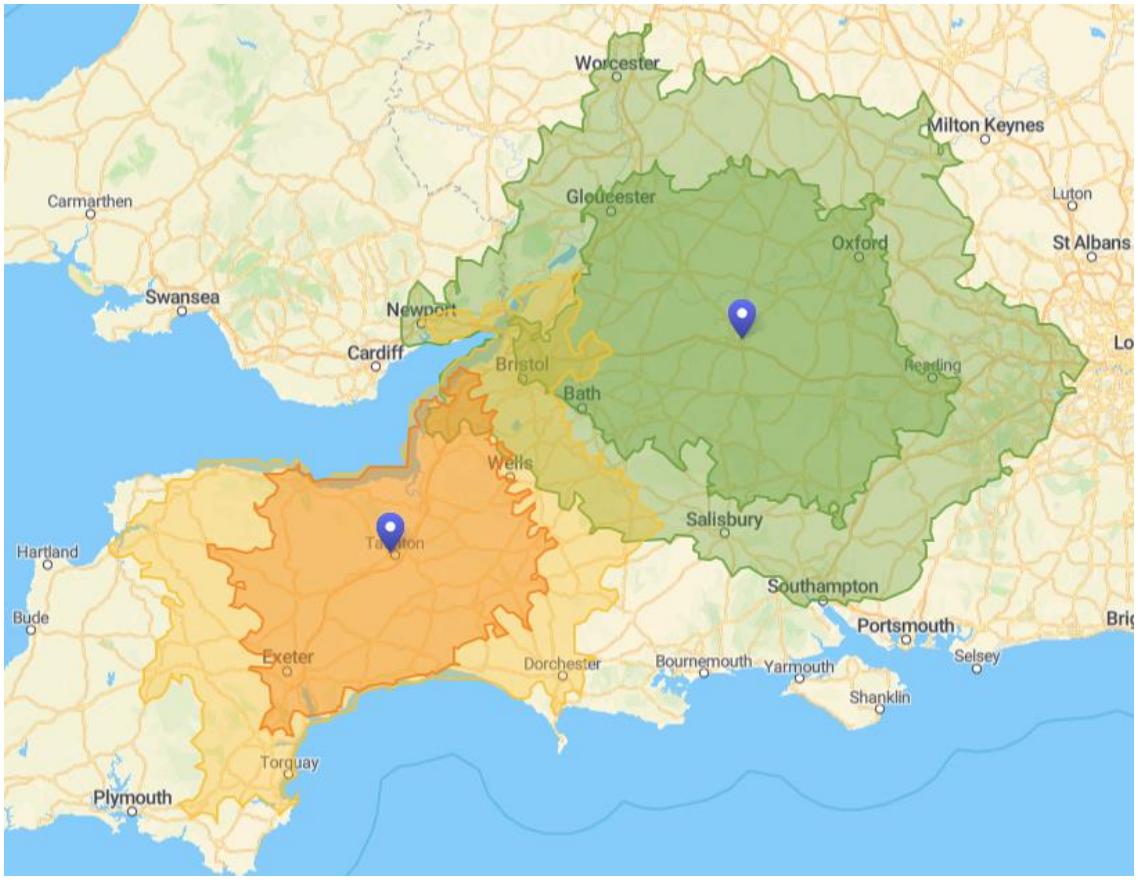
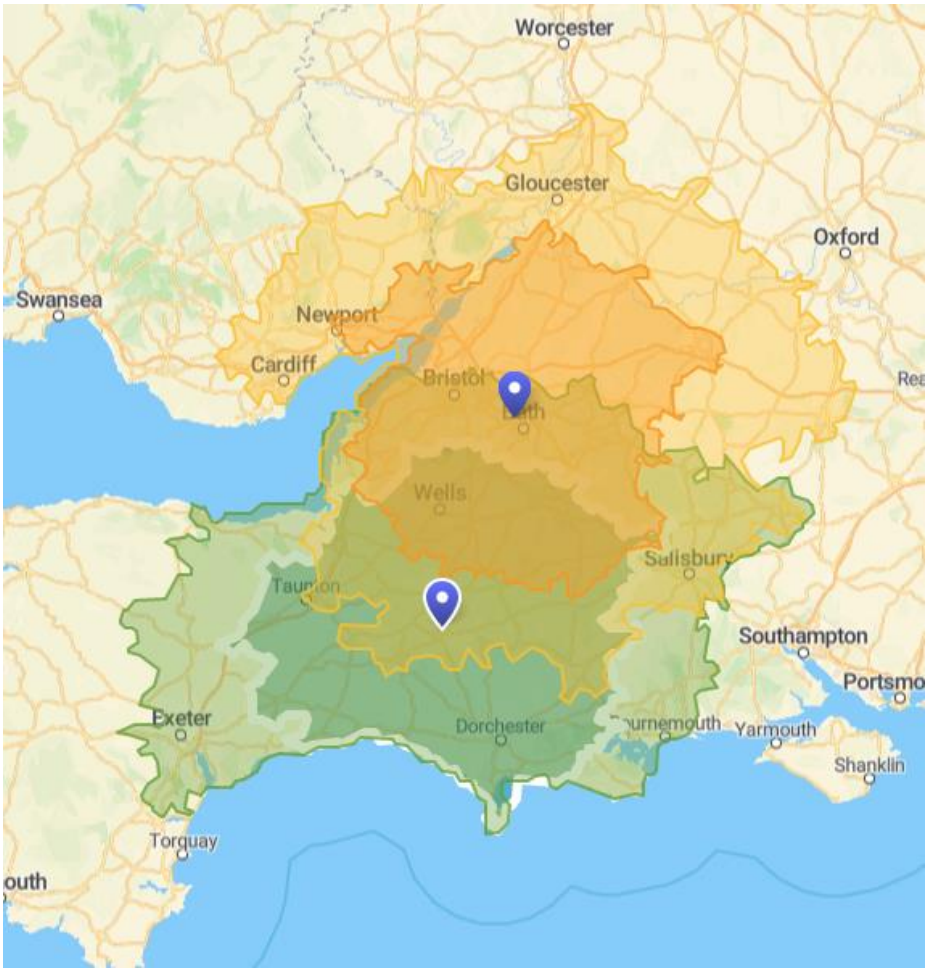
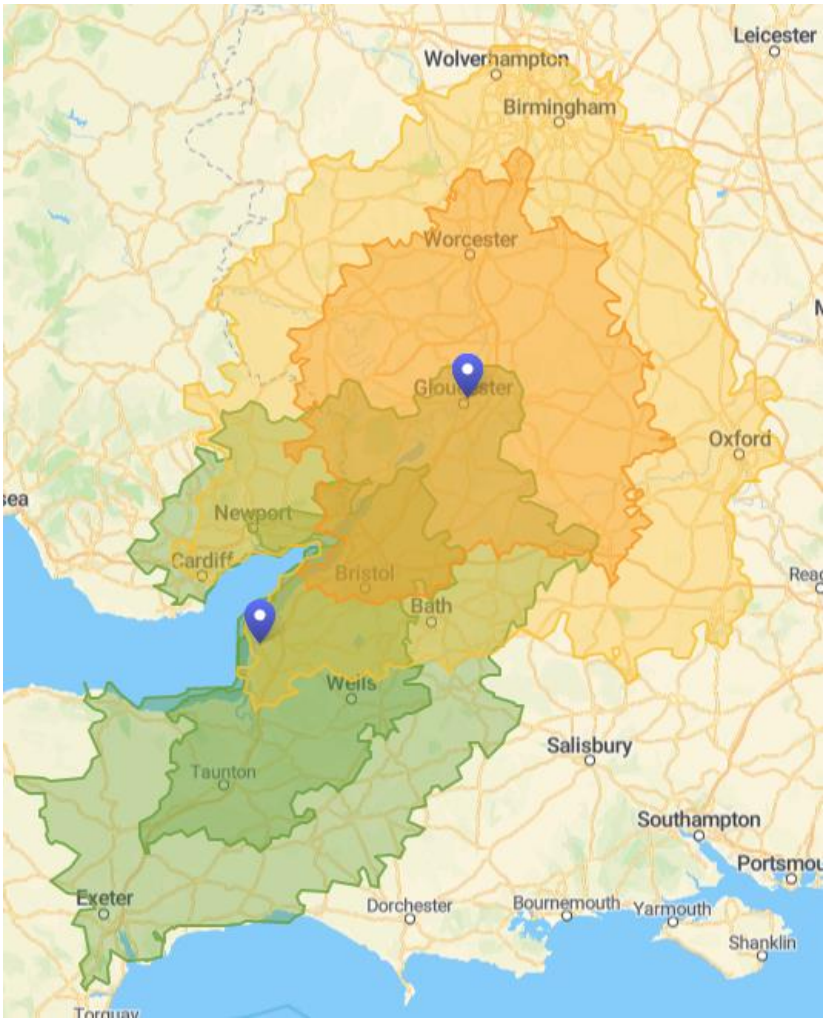


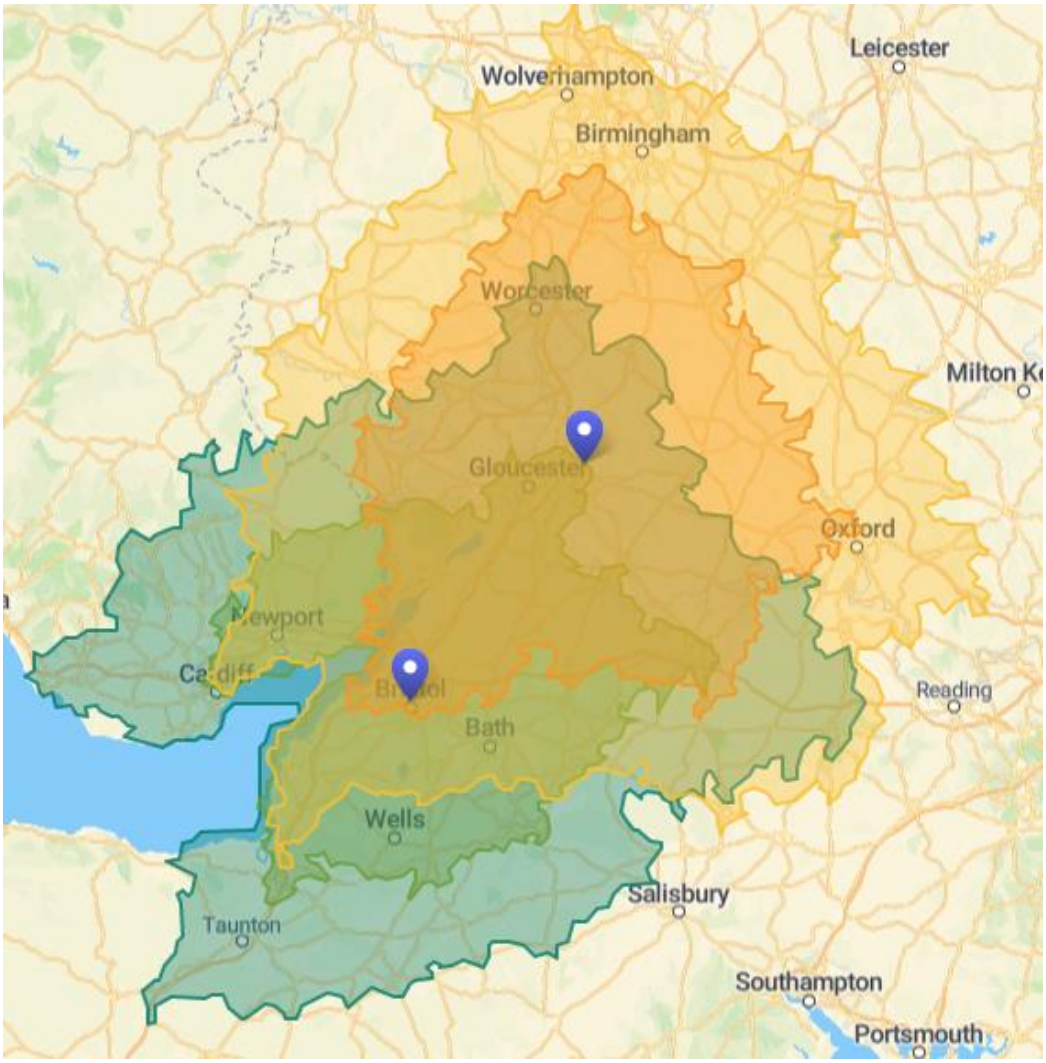
Musgrove Park, GWH Swindon



Yeovil, Bath



Weston-super-Mare, Gloucester



Bristol Hospitals, Cheltenham

Appendix 2 – achievable destinations for each hospital (based on example oxygen requirements alone; calculate for your patient)

		NIV/CPAP	HFNO
Peninsula	Royal Cornwall	Derriford Hospital	-
	Derriford Hospital	RD&E Hospital Torbay Hospital Royal Cornwall Hospital	Torbay Hospital
	Torbay Hospital	Derriford Hospital RD&E Hospital	Derriford Hospital RD&E Hospital
	Royal Devon & Exeter Hospital	Derriford Hospital Torbay Hospital Musgrove Park Hospital	Derriford Hospital Torbay Hospital
	North Devon District Hospital	RD&E Hospital Musgrove Park Hospital	-
Severn	Musgrove Park Hospital	RD&E Hospital Yeovil Hospital Bristol Royal Infirmary Southmead Hospital Weston General Hospital Dorset County Hospital	RD&E Hospital Yeovil Hospital Weston General Hospital
	Yeovil District Hospital	Musgrove Park Hospital Dorset County Hospital University Hospitals Dorset, Poole RD&E Weston General Hospital Bristol Royal Infirmary Southmead Hospital Royal United Hospital Salisbury District Hospital	Musgrove Park Hospital Dorset County Hospital University Hospitals Dorset, Poole
	Weston General Hospital	Musgrove Park Hospital Bristol Royal Infirmary Southmead Hospital Royal United Hospital RD&E Gloucestershire Royal Hospital Cheltenham General Hospital	Musgrove Park Hospital Bristol Royal Infirmary Southmead Hospital
	Bristol Royal Infirmary/Southmead Hospital	Bristol Royal Infirmary Southmead Hospital Royal United Hospital Weston General Hospital Great Western Hospital Royal Gwent Hospital, Newport Gloucestershire Royal Hospital Cheltenham General Hospital University Hospital Wales, Cardiff	Bristol Royal Infirmary Southmead Hospital Royal United Hospital Weston General Hospital Great Western Hospital Royal Gwent Hospital, Newport Gloucestershire Royal Hospital Cheltenham General Hospital
	Royal United Hospital	Weston General Hospital Bristol Royal Infirmary Southmead Hospital	Bristol Royal Infirmary Southmead Hospital Royal United Hospital

		Great Western Hospital Musgrove Park Hospital Yeovil Hospital University Hospital Wales, Cardiff Royal Gwent Hospital, Newport Gloucestershire Royal Hospital Cheltenham General Hospital	Great Western Hospital Weston General Hospital Royal Gwent Hospital, Newport
	Great Western Hospital	John Radcliffe Bristol Royal Infirmary Southmead Hospital Royal United Hospital Gloucestershire Royal Hospital Cheltenham General Hospital Royal Berkshire, Reading Royal Gwent Hospital, Newport Salisbury District Hospital University Hospitals Southampton Weston General Hospital	John Radcliffe Bristol Royal Infirmary Southmead Hospital Royal United Hospital Gloucestershire Royal Hospital Cheltenham General Hospital Royal Berkshire, Reading
	Gloucestershire Royal Hospital	Cheltenham General Hospital Worcestershire Royal Hospital Great Western Hospital Bristol Royal Infirmary Southmead Hospital Weston General Hospital John Radcliffe Various Wolverhampton and Birmingham Hospitals	Cheltenham General Hospital Worcestershire Royal Hospital Great Western Hospital
	Cheltenham General Hospital	Gloucestershire Royal Hospital Worcestershire Royal Hospital Great Western Hospital Bristol Royal Infirmary Southmead Hospital Weston General Hospital John Radcliffe Various Wolverhampton and Birmingham Hospitals	Gloucestershire Royal Hospital Worcestershire Royal Hospital Great Western Hospital

Appendix 3 – H900 humidification set up

H900 Setup

1. Place Hamilton H900 on metal bracket located on support pole next to LSU.
2. Plug H900 into trolley circuit board using kettle lead. The H900 will only work when connected to mains or inverter power.
3. Inspect water chamber for damage before use. Carefully insert BC8 water chamber onto H900 hot plate.
4. Connect BC8 dual limb tubing to Hamilton T1; disconnecting normal Hamilton tubing leaving exhaust valve in place. Place a viral filter between white limb of BC8 and exhaust valve. Small arrows on tube connectors indicate the correct placement. White tube is expiratory, and the blue tube is inspiratory.
5. Attach Hamilton flow sensor on Y-piece at the end of dual limb circuit. Place viral filter at end of Y-piece. Attach plastic tubing to Hamilton T1 flow ports.
6. Spike inhalation fluid and hang on drip stand located near top of Ferno trolley.
7. Select correctly sized NIV mask / nasal specs and start ventilation.

NIV specific setup

1. While connected to power, turn H900 on. This will automatically heat to a temperature of 37 degrees on the NIV setting and take 7-8 minutes to reach temperature. This can be prepared before arrival to avoid delay. Please use default settings unless clinically indicated.
2. Turn Hamilton T1 on and select NIV mode. Confirm NIV settings: either NIV (PEEP/Psupport) or NIV ST (Spontaneously-Timed – if rate drops below set value mandatory timed breaths are delivered).

Select either large or medium facemask for NIV and secure to patient avoiding pinching skin or hair. NIV circuits need an HME valve to protect the ventilator. When finished; the H900 will cool at 6 degree C in the first hour. Please do not remove water chamber from hot plate unit cooled.

Appendix 4 – H900 troubleshooting

Alarm Type	Reason(s)	Resolution
High Priority • Red flashing light with icon for reason on display. • Continual beeping alarm until alarm reset. • Needs immediate attention.	• Humidifier tilted at a greater angle than 10 percent • Temperature higher than set value at Y piece • Technical Faults (TF) – for example incorrect tube placement or leaking chamber • Water level high	• Check mounting to prevent tilt • Ensure breathing circuit tubing is not covered by blizzard blanket or covers. Replace circuit If continues • Check tube connections or replace circuit if recognised leak • Empty water chamber
Medium Priority • Yellow flashing light with icon on display. • 3 consecutive beeps until alarm is reset.	• Temperature below set value • Water level low • Circuit Limb Fault	• System can take up to 30 minutes to heat up. Mitigate this alarm by preheating • Refill and replace inhalation fluid • Ensure limbs connected to correct ports. Check no kinks. Replace circuit • Warm ambulance temperature • Wrap Hamilton T1 Tubing circuits with Hamilton tubing cover
• To silence alarm, push the pause alarm button located on the front on the device. • To adjust alarm volume press and hold for 3 seconds and adjust using slider bar.		

Appendix 5 – Hamilton T1 Troubleshooting NIV and HFNO

Specific NIV Alarms Due to the changing and unpredictable amount of leakage, volume alarms are less meaningful in non-invasive modes than in other modes. **To avoid nuisance alarms, set low Vt and ExpMinVol alarm to low levels.**		
Alarm	**Reason**	**Resolutions**
High Priority • Red flashing light with icon for reason on display • Continual beeping alarm until alarm reset • Needs immediate attention • Addition information on alarms can be found in the Hamilton T1 SOP	**High Peak Pressure** • Reasons for high pressure alarm/occlusion can be mechanical or patient interface including patient cough, apnoea or kinking of tubing	• Hamilton T1 will automatically switch to PCV+ mode with PControl set to 15 for 10 seconds • Check patient • If pressure reduces auto switch made back to NIV mode(s). If ventilator does not switch this could be due to flow sensor failure – connect and calibrate new flow sensor • **Peak pressures >33cmH2O may increase risk of aspiration**
Medium Priority • Yellow flashing light with reason on display	**Low pressure** • Reasons for low pressure alarm, can indicate significant leak or disconnection	• Ensure facemask fitting correctly. Tighten straps or readjust to ensure correct fitting. Check patient interface for blockage • Look for disconnection on along tubing. • **Additional components, such as an HMEF, between the flow sensor and the patient, can limit the ventilator's ability to identify disconnection at the patient**
HFNO Alarms		
Medium Priority • Yellow flashing light with reason on display	**Check for Blockage** • If pressure exceeds the high pressure limit of 45 cmH_2O	• Check patient interface and ensure nasal prongs situated correctly • Check tracheostomy site for blockage. Exchange inner tube • Provide suction

Appendix 6 – Storage

At present H900 and humidification kit is stored within a red bag within the ambulance above practitioner seats. Kit includes:

- Hamilton H900 Humidification Device
- Full Face Mask L and M
- Hamilton 'In2flow' Nasal Cannula and Adapter
- Optiflow Tracheostomy Direct Connection Device
- Hamilton Flow sensor set (Needed only for NIV)
- Hamilton BC8 Breathing circuit (dual limb) with a heated water chamber (does not fit in the current bag)
- Single Expiratory valve (to save normal HT1 Set)
- Ventilator viral filter x2
- H900 kettle lead