Use of Highflow in Transport

This guideline is for use by healthcare staff, at CoMET undertaking critical care retrieval, transport and stabilisation of children, and young adults.

CoMET is a Paediatric Critical Care Transport service and is hosted by the University Hospitals of Leicester NHS trust working in partnership with the Nottingham University Hospitals NHS Trust.

The guidance supports decision making by individual healthcare professionals and to make decisions in the best interest of the individual patient.

This guideline represents the view of CoMET, and is produced to be used mainly by healthcare staff working for CoMET, although, professionals, working in similar field will find it useful for easy reference at the bedside.

We are grateful to the many existing paediatric critical care transport services, whose advice and current guidelines have been referred to for preparing this document. Thank You.

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Education and Training

1. Annual Transport team update training days
2. Workshops delivered in Regional Transport Study days/ Outreach

Monitoring Compliance

What will be measured to monitor compliance	How will compliance be monitored	Monitoring Lead	Frequency	Reporting arrangements
Incident reporting	Review related Datix	Abi Hill – Lead Transport Nurse abi.hill@uhl-tr.nhs.uk	Monthly	CoMET Lead Governance Meeting
Documentation Compliance	Documentation Audit	Abi Hill – Lead Transport Nurse abi.hill@uhl-tr.nhs.uk	3 Monthly	CoMET Lead Governance Meeting

Use of High Flow in Transport

1. Indications and contraindications for HFNC

1.1 Indications for HFNC

HFNCT is used for the same indications as the traditional method of CPAP for:

- Bronchiolitis.
- Viral induce wheeze
- Pneumonia

(Complex needs and/or Cardiac conditions are not a contraindication to HFNCT).

Clinical parameters suggesting the need for HFNCT

- Respiratory rate > 60 breaths/min in babies with bronchiolitis
- Apnoeas, bradypnoea or cyanotic episodes (with or without bradycardia) despite supplemental O_2
- Severe intercostal recession and indrawing
- Need for > 2 L/min O_2 via nasal prongs or 60% O_2
- $PaCO_2$ 6.5 kPa or more (in children without pre-existing chronic lung disease)
- Rising $PaCO_2$ (> 2 kPa from baseline)

*Respiratory acidosis if pH < 7.20 consider ventilation

1.2 Cautions to the use of HFNCT

- Upper airway abnormalities that may make HFNCT, NCPAP, or Nasal Mask (NM) CPAP ineffective or potentially dangerous (e.g. choanal atresia, cleft palate or tracheoesophageal fistula)
- Severe cardiovascular instability and impending arrest
- Air leak: Pneumomediastinum or Pneumothorax (if not drained)
- Maxillofacial trauma
- Suspected basal skull fracture
- Decreased level of consciousness
- Foreign body aspiration
- Open chest wound/trauma
- Multi-organ compromise
- Respiratory acidosis (pH< 7.2)
- Severe apnoea

1.3 Complications of HFNCT

Potential complications of HFNCT therapy to consider:

- Potential barotrauma leading to surgical emphysema / pneumothoraxes, especially if cannulae occupy more than 50% of the diameter of the nares.

- Gastric distention (NG on free drainage may be appropriate) and diaphragmatic splinting
- Obstruction or irritation due to improper sizing of nasal cannulas
- Blocked HFNC due to secretions

2. Management of High Flow on transport

Patients transferred on high flow by CoMET shall fall into two categories:

1. **Acute unplanned transfers- High flow initiated by CoMET**- those patients who are spontaneously ventilating in air or oxygen at the referring unit and who are assessed by CoMET team to require an increased level of support.
    a. Treatment will be initiated after consultation with CoMET consultant on call taking into account any cautions, or whether significantly increased level of support is required e.g. NCPAP or intubation and ventilation.
    b. Ensure that the receiving unit is able to take the child on this mode of therapy
2. **Acute planned transfers- Continuing high flow therapy by CoMET-** those patients who are already established on high flow at the referring centre.
    a. These patients will make up the majority of the high flow transfers with the aim that CoMET can mimic the setting used by the referring centre as closely as possible.

Prior to transfer:

Gas consumption needs to be considered prior to transfer, as there is a high risk for running out of oxygen (see appendix 3). This is a NEVER event and if this is considered a risk should be discussed with CoMET consultant on duty.

3. Equipment required for HFNC

Ventilator:

The Hamilton T1 is the ventilator of choice for delivering high flow in transport. Depending on the circuit and interface resistance, higher pressures may be required to deliver the set flow. Pressure is measured inside the ventilator. If pressure exceeds the high pressure limit of 50 cmH_2O, the gas stops immediately and pressure is released. Flow resumes after 8 seconds (adult/paed) or 4 seconds (neo) at the set flow rate.

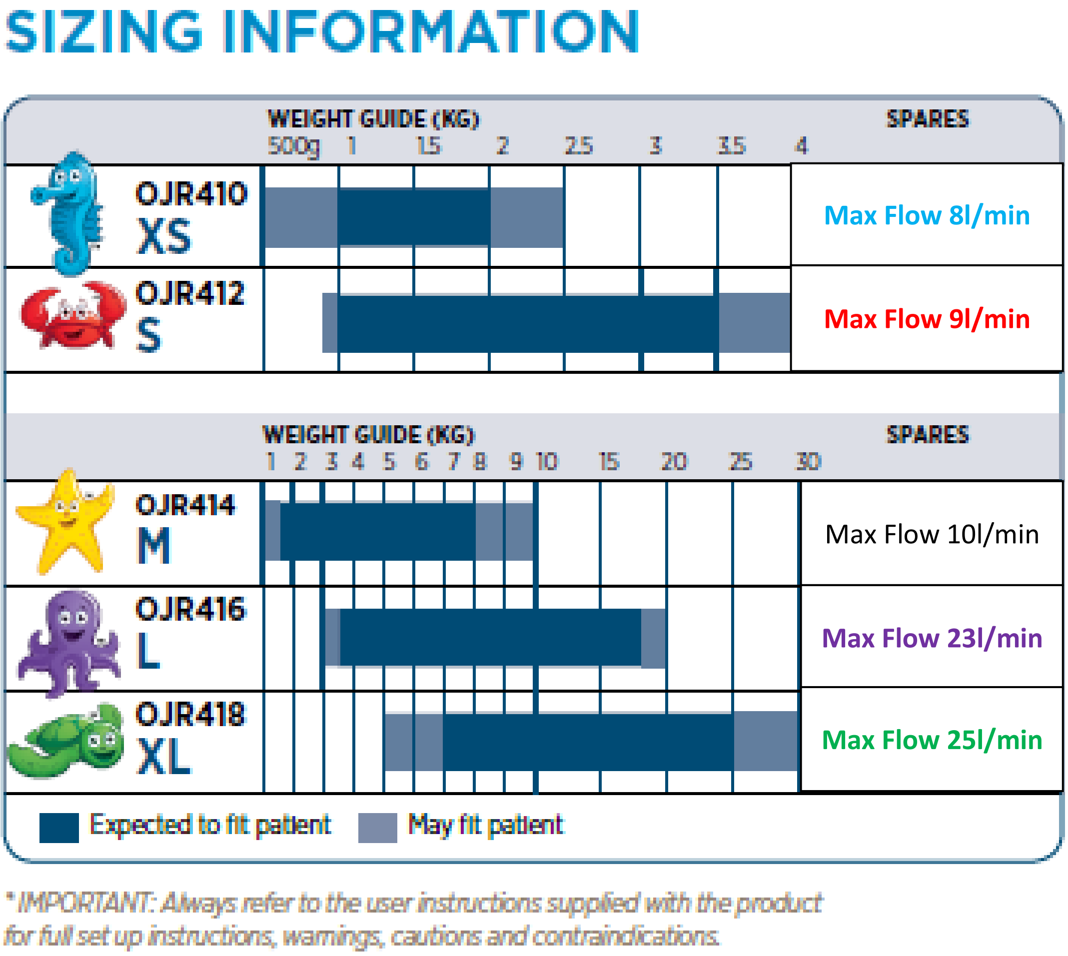
Humidification:

Active humidification during high flow oxygen therapy must always be used. Please see Appendix 2 for additional system set-up. This must ALWAYS be BELOW patient level to prevent backflow of water up tubing which could cause facial burns.

Nasal Cannula:

The leak around the cannula protects the child against excessive PEEP and allows for greater CO_2 washout compared to nasal CPAP. As the flow rate increases so does the positive airways pressure. As the weight of the child increases, the positive airway pressure at a given flow rate reduces. Thus, different sized cannulae are provided for different weight children and gas flow is adjusted to produce a clinical improvement. However, it should be noted, that the positive airway pressure is not measured and this is one of the concerns around its use.

Nasal cannula should be selected appropriate to the patient. **These must not occlude more than 50% of the patient's nares.** This ensures that CO_2 washout is optimised and reduces the risk of pneumothorax.



(Optiflow Junior 2 User Instructions)

The maximum flow rates above describe technical capability of the product when used at sea level

NB. Please ensure that you do not exceed the maximum flow for the cannula selected.

3.1 HFNCT initial settings:

FiO2:

- Set target SpO_2 for child (normally 92 -95%) may need to be lower in children with chronic lung disease or congenital heart disease.
- Start with 60%- and wean quickly

Flow:

Weight (kg)	≤12	13-15	16-30	31-50	>50
Starting flow rate	2 l/min/kg	25-30 l/min	35 l/min	40 l/min	50 l/min
Weaning flow rate	1 l/min/kg	13-15 l/min	18 l/min	20 l/min	25 l/min

(Richards-Belle A 2020)

Flow rate for transport are limited to 40l/min due to cylinder oxygen

Monitoring

All patients requiring respiratory support should have:

- Continuous HR and SpO_2 monitoring
- Hourly recording of observations (RR, HR, SpO_2) for the first 2 hours and every 15 minutes during transport.
- Fluid balance

Assessment

Reassess patient status regularly- please refer to Appendix 1 for high flow interventions. The success and failure of treatment can be guided by the following:

Success of treatment:

- Reduction in frequency/ severity of apnoea
- Reduction in oxygen requirement
- Reduction in heart rate and respiratory rate (evidence suggests possible within first 90 minutes)
- Improvement in respiratory acidosis
- Reduction in work of breathing

If HFNCT is failing: i.e. no improvement after 2 hours

- Consultant review or contact via call conferencing
- Consider escalation to CPAP or intubation

Patient nursing care

- All infants on high flow should have a nasogastric tube
- Nasogastric tube should be on free drainage during transport to prevent gastric distension and alleviate WOB. Please aspirate prior to departure.
- Once stable on high flow, the infant should be assessed as to whether they can feed. NB This will not be considered until transfer complete and children will be managed on IV fluids in the interim.
- Note nasal prongs are in correct position and no pressure areas to nares

- Check humidifier water level hourly and every 15 minutes in the ambulance. Ensure that the level of water does not exceed the halfway mark- please ensure that the water line is clamped to prevent over filling.
- Check circuit (kinks or tangled) and nasal cannulae position (ensure no nasal obstruction)

References:

Westrope C (2018) **Humidified High Flow Nasal Cannula (HHFNC) Oxygen Therapy.** Leicester Royal Infirmary Children's Hospital

Gilhooley C, Silvestre C, McHale S(2016) **Guideline for HFNCT (High Flow Nasal Cannula Therapy)** Nottingham Children Hospital

Richards-Belle A et al (2020) FIRST-line support for assistance in breathing in children (FIRST-ABC): a master protocol of two randomised trials to evaluate the non-inferiority of high-flow nasal cannula (HFNC) versus continuous positive airway pressure (CPAP) for non-invasive respiratory support in paediatric critical care **BMJ Open**. 2020 Aug 4;10(8):e03

Indications:
HFNCT is used for the same indications as the traditional method of CPAP:

- Bronchiolitis.
- Viral induce wheeze
- Pneumonia

Clinical parameters suggesting the need for HFNCT

- Respiratory rate > 60 breaths/min
- Apnoeas, bradypnoea or cyanotic episodes (with or without bradycardia) despite supplemental O_2
- Severe intercostal recession and indrawing
- Need for > 2 L/min O_2 via nasal prongs or 60% O_2
- $PaCO_2$ 6.5 kPa or more (in children without pre-existing chronic lung disease)
- Rising $PaCO_2$ (> 2 kPa from baseline)

Appendix 1:
High Flow interventions

Cautions

- Upper airway abnormalities e.g. choanal atresia, cleft palate or tracheoesophageal fistula
- Severe cardiovascular instability and impending arrest
- Air leak: Pneumomediastinum or Pneumothorax (if not drained)
- Maxillofacial trauma
- Suspected basal skull fracture
- Decreased level of consciousness
- Foreign body aspiration
- Open chest wound/trauma
- Multi-organ compromise
- Respiratory acidosis (pH< 7.2)
- Severe apnoea

Indications and contraindications for starting HFNC are considered

↓

Commence FiO_2 at 60%
Flow rate as per table (see page 4)

↓

SpO_2 <92%

↓ Increase FiO_2 to 80%

↓ SpO_2 <92%

↓ Exclude causes for failure:

- Nasal obstruction
- Pneumothorax
- Gastric distension leading to diaphragmatic splinting
- Check circuit is not kinked or tangled
- Check nasal cannula position

↓ SpO_2 <92%

↓ Consider increasing flow & discuss CoMET consultant

↓ SpO_2 <92%

↓ Increase FiO_2 to 100% whilst considering need for CPAP or intubation- CALL CoMET CONSULTANT

SpO_2 92-95%

↓ Continue therapy with frequent reassessment

SpO_2 >95%

↓ Reduce FiO_2 by 10%

↓ SpO_2 >95%

↓ Consider Reducing FiO_2 further in 10% alliquots

↓ SpO_2 >95%

↓ Consider Reducing flow by 10%

NB. ENSURE OXYGEN CALCULATION HAS BEEN COMPLETED PRIOR TO TRANSFER

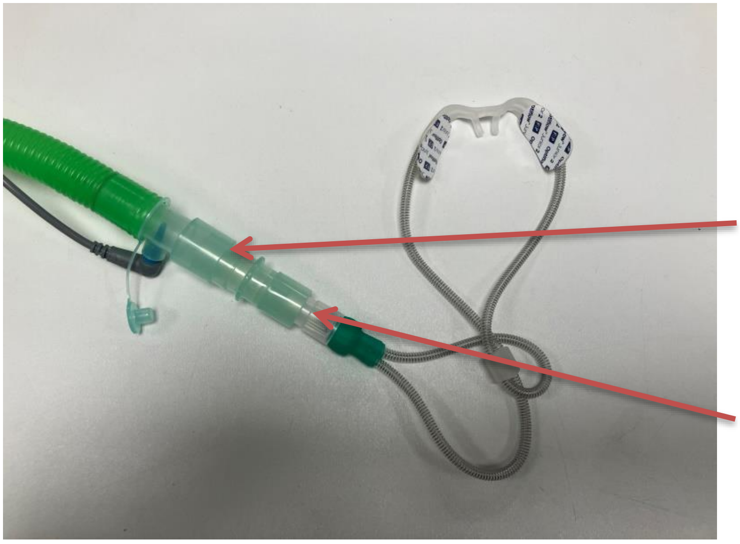
Appendix 2: High Flow for Hamilton T1

High Flow must not be used without the ability to humidify in the ambulance as this may cause patient airway damage. Full oxygen calculation must be completed prior to considering this mode of therapy- see Appendix 3.

Set up the humidifier as shown in the picture to the left using either a green intersurgical humidified circuit (reference 2025310 – 22MM flextube single heated wire breathing system)- discarding the expiratory limb and water trap as these are not required **or** the Fisher& Paykel RT202 single limb circuit (22mm circuit).

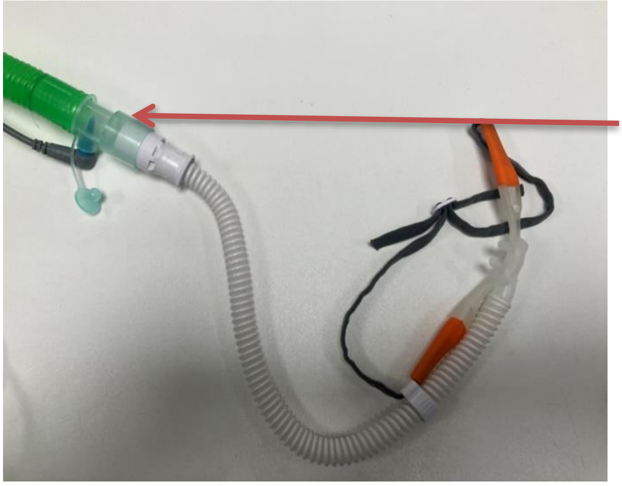
Ensure the heater wires are plugged in the humidifier and patient end of circuit. Insert filter on inspiratory outlet of ventilator and connect the short tubing from the inhalation port to the humidification chamber, and the heated wire from the humidifier to the patient interface, ensuring that the temperature probes are connected to the circuit.

Remove expiratory valve as this is not required.



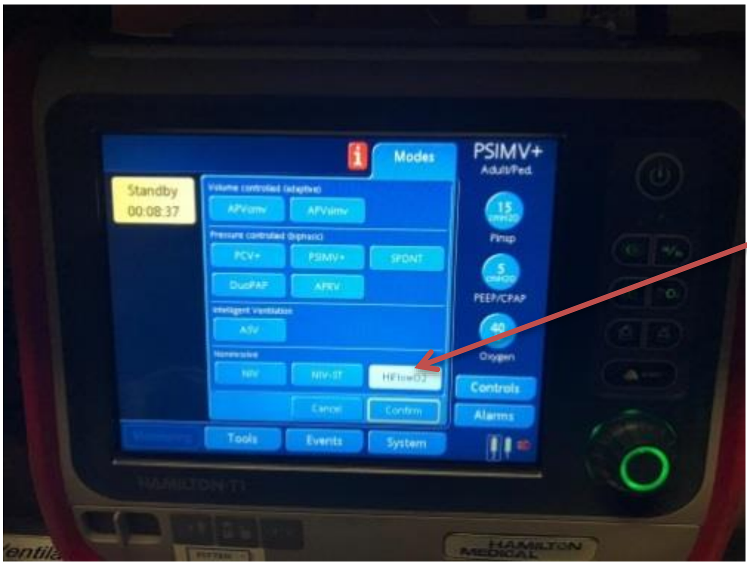
Attach the high flow nasal cannula to the intersurgical ventilator circuit.

You will require a green 1969 connector (straight connector 22M – 22M / 15F) on the end of the ventilator tubing and then a clear connector to connect to the paediatric cannula (the clear connectors come with the paediatric high flow cannula sets - these are not currently available separately)



The adult cannula will not require any additional connectors – the cannula will connect directly onto the intersurgical ventilator tubing

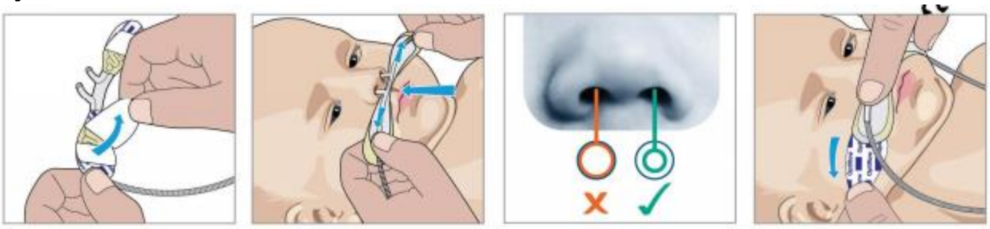
On the main screen select the adult / paediatric setting. High flow will not appear as one of the three main modes of ventilation so you will need to select the modes button in the top right hand corner of the screen



Select ‘high flow’ - this is located at the bottom of the screen to the right

Set the flow / oxygen required and commence high flow ventilation

To apply cannula



To apply cannula:

1. Select the appropriate size- see table on page 4. The prongs should not fill the nares and a clear gap should be visible around each prong.
2. Ensure the skin is dry.
3. Connect system to gas source. Place hand close to the nasal prongs to ensure there is airflow exiting the prongs.
4. Remove first the wiggle pads backing tabs without touching the adhesive.
5. Position the prongs high up into the nares such that the cannula bridge rests just underneath the septum. Stick wiggle pads to each cheek.
6. Remove second backing tabs and stick wiggle pads to the cheeks.

During use please ensure the following:

1. Ensure the cannula does not apply pressure to the septum. A slight gap should be present.
2. Ensure tubing does not apply excessive pressure to the ears or face.
3. Ensure that there are no secretions that could cause the prongs to seal in the nares.
4. Ensure that all connections are secure during use. Check that the cannula is undamaged and that the flow path is maintained.

Important Points to consider:

1. High flow should only be commenced on the green or yellow trolley as these include the humidifier.
2. Humidifier should be set at Invasive mode (up to 41oC).
3. The humidifier should always be lower than the patient.
4. Ensure the humidifier isn't over filled. The reservoir is pre-filling however please ensure that you use plastic clamps to prevent it filling to the maximum level (fill only halfway- this will avoid high current draws). During transfer you will need to keep an eye on this level and fill as required. The water bag should be hung securely somewhere it can't drip onto electrics.
5. Always preheat the humidifier to desired temperature whilst being attached to a mains power supply prior to connecting in ambulance. This is to reduce the power needed for heating and can be done prior to departure at base or prior to departure in referral hospital.
6. When converting from optiflow/vapotherm the patient may need some tweaks to the settings and system set up. The Vapotherm has a blow off pressure of 200mmHg whereas the Hamilton is only 50mmHg- if this pressure is reached the Hamilton will stop delivering flow for approx. 8 seconds. You may need to consider either a larger diameter prong (bearing in mind that the prongs do not fully obstruct the nostril which can lead to high pressure and patient injury) or reduce the flow.
7. Ensure the trolley is plugged into the mains supply when the humidifier is in use (as it will not run on battery supply) and ensure when in the ambulance that the trolley is plugged in and charging at all times.

Appendix 3: Oxygen consumption for High Flow

Gas consumption needs to be considered prior to transfer, as there is a high risk for running out of oxygen. This is a NEVER event and if this is considered a risk should be discussed with CoMET consultant on duty.

Table 1 (below) highlights the oxygen consumption of the Hamilton based on different flow rates and oxygen concentrations.

Table 1:

Flow Rate	Oxygen Concentration (%)											
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	100%
6l/min	0.3	0.7	1.1	1.4	1.8	2.2	2.6	2.9	3.2	3.5	4.2	5.6
8l/min	0.4	0.9	1.2	1.9	2.1	2.9	3.1	3.9	4.3	4.8	5.7	7.5
10l/min	0.5	1.1	1.8	2.4	3	3.7	4.3	4.9	5.5	6.3	6.9	9.3
12l/min	0.6	1.4	2.1	2.9	3.6	4.4	5.1	5.9	6.1	7.3	8.7	11.2
14l/min	0.7	1.6	2.4	3.3	4.2	5	5.9	6.7	7.6	8.5	10.2	12.9
16l/min	0.8	1.8	2.8	3.5	4.7	5.4	6.7	7.7	8.6	9.6	11.5	14.6
18l/min	0.9	2	3.1	4.2	5.3	6.3	7.4	8.5	9.6	10.7	12.9	16.3
20l/min	1	2.2	3.4	4.7	5.8	7	8.2	9.2	10.7	11.9	14.3	19.1
25l/min	1.3	2.8	4.4	5.9	7.5	9.1	10.6	12.2	13.7	15.3	18.4	24.6
30l/min	1.5	3.4	5.3	7.1	9	10.9	12.7	14.6	16.4	18.3	22	29.4
35l/min	1.8	4	6.1	8.3	10.5	12.7	14.8	17	19.1	21.3	25.6	34.3
40l/min	2	4.5	7	9.5	11.9	14.4	16.9	19.4	21.8	24.3	29.3	39.1
45l/min	2.2	5	7.8	10.6	13.4	16.2	19	21.7	24.5	27.3	32.3	43.9
50l/min	2.5	5.6	8.7	11.8	14.9	18	20.5	23.6	26.7	29.8	35.8	49

When calculating the amount of oxygen required for a journey you need to consider the safety factor of 2.

Oxygen consumption (L/min) (see table 1) X Journey time (mins) X 2 (Safety factor) = Oxygen Requirement (litre)

Once you have calculated you oxygen requirement you can then calculate how long your cylinder will last for.

$$\frac{\text{Cylinder contents (litres)}}{\text{Gas consumption (litres/min)}} = \text{Time cylinder will last (min)}$$

Cylinder Type	Volume
E (trolley)	680L
ZX	3040L (x2 stored on the ambulance)

CoMET is limited by 2 factors when considering high flow for transport:

1. The trolley oxygen supply to get the child from base to ambulance and ambulance to destination.
2. The ambulance oxygen supply available for the road journey.

In light of this it would be unwise to transfer any patients who require a higher oxygen consumption of more than 20L/min based on the time available on the E cylinder to transfer from bedside to ambulance. (NB. Unless you are able to replenish your gases prior to departure at this stage to allow for the repeat return journey from ambulance to base).

Based on the Hamilton oxygen consumption we have also produced a guide to how long each of the cylinders available in the ambulance will last (see table 2 & 3). These tables have taken into account both the safety factor based on the practical application that a certain level of driving force from the cylinder is required (based ¾ of the cylinder volume).

When considering a high flow transfer the team need to calculate the anticipated length of their journey building in the safety factor of 2. The team therefore in essence need to ensure they can complete the planned journey on one E cylinder for the journey between bedsides and ambulance (the second cylinder allows for the safety factor) and 1 cylinder in the ambulance (the second cylinder needs to be full to allow for the safety factor)

Table 2: E Cylinder (680Litres)

Approx. length of time (mins) that an E cylinder (680L) will last at various flow rates and FiO_2

	Oxygen Concentration (%)											
Flow Rate	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	100%
6l/min	1700	729	464	364	283	232	196	176	159	146	121	91
8l/min	1275	567	425	268	243	176	165	131	119	106	89	68
10l/min	1020	464	283	213	170	138	119	104	93	81	74	55
12l/min	850	364	243	176	142	116	100	86	84	70	59	46
14l/min	729	319	213	155	121	102	86	76	67	60	50	40
16l/min	638	283	182	146	109	94	76	66	59	53	44	35
18l/min	567	255	165	121	96	81	69	60	53	48	40	31
20l/min	510	232	150	109	88	73	62	55	48	43	36	27
25l/min	392	182	116	86	68	56	48	42	37	33	28	21
30l/min	340	150	96	72	57	47	40	35	31	28	23	17
35l/min	283	128	84	61	49	40	34	30	27	24	20	15
40l/min	255	113	73	54	43	35	30	26	23	21	17	13
45l/min	232	102	65	48	38	31	27	24	21	19	16	12
50l/min	204	91	59	43	34	28	25	22	19	17	14	10

(NB. The above table has taken in to account that the cylinder requires being ¼ full to drive the ventilator i.e it works on the assumption we have 510L available rather than the full 680L)

NB For transfers within region only:	
(amber)	Consultant decision
(red)	Do not transfer on HFNC
(red hatched)	Unable to facilitate due to max flow on cylinders being 40l/min

Table 3: ZX Cylinder (3040Litres)

Approx. length of time (mins) that ZX cylinder (3040L) will last at various flow rates and FiO_2 taking into account potential driving force of cylinder

	Oxygen Concentration (%)											
Flow Rate	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	100%
6l/min	7600	3257	2073	1629	1267	1036	877	786	713	651	543	407
8l/min	5700	2533	1900	1200	1086	786	735	585	530	475	400	304
10l/min	4560	2073	1267	950	760	616	530	465	415	362	330	245
12l/min	3800	1629	1086	786	633	518	447	386	374	312	262	204
14l/min	3257	1425	950	691	543	456	386	340	300	268	224	177
16l/min	2850	1267	814	651	485	422	340	296	265	238	198	156
18l/min	2533	1140	735	543	430	362	308	268	238	213	177	140
20l/min	2280	1036	671	485	393	326	278	248	213	192	159	119
25l/min	1754	814	518	386	304	251	215	187	166	149	124	93
30l/min	1520	671	430	321	253	209	180	156	139	125	104	78
35l/min	1267	570	374	275	217	180	154	134	119	107	89	66
40l/min	1140	507	326	240	192	158	135	118	105	94	78	58
45l/min	1036	456	292	215	170	141	120	105	93	84	71	52
50l/min	912	407	262	193	153	127	111	97	85	77	64	47

(NB. The above table has taken in to account that the cylinder requires being ¼ full to drive the ventilator i.e it works on the assumption we have 2280L available rather than the full 3040L)

	NB For transfers within region only:
(amber)	Consultant decision
(red)	Do not transfer on HFNC
(red hatched)	Unable to facilitate due to max flow on cylinders being 40l/min

HX Cylinder (2300Litres)

Approx. length of time (mins) that HX cylinder (2300L) will last at various flow rates and FiO_2 taking into account potential driving force of cylinder

	Oxygen Concentration (%)											
Flow Rate	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	100%
6l/min	5750	2464	1568	1232	958	784	663	595	539	493	411	308
8l/min	4313	1917	1438	908	821	595	556	442	401	359	303	230
10l/min	3450	1568	958	719	575	466	401	352	314	274	250	185
12l/min	2875	1232	821	595	479	392	338	292	283	236	198	154
14l/min	2464	1078	719	523	411	345	292	257	227	203	169	134
16l/min	2156	958	616	493	367	319	257	224	201	180	150	118
18l/min	1917	863	556	411	325	274	233	203	180	161	134	106
20l/min	1725	784	507	367	297	246	210	188	161	145	121	90
25l/min	1327	616	392	292	230	190	163	141	126	113	94	70
30l/min	1150	507	325	243	192	158	136	118	105	94	78	59
35l/min	958	431	283	208	164	136	117	101	90	81	67	50
40l/min	863	383	246	182	145	120	102	89	79	71	59	44
45l/min	784	345	221	163	129	106	91	79	70	63	53	39
50l/min	690	308	198	146	116	96	84	73	65	58	48	35

(NB. The above table has taken in to account that the cylinder requires being ¼ full to drive the ventilator i.e it works on the assumption we have 1725L available rather than the full 2300L)

NB For transfers within region only:	
(orange)	Consultant decision
(red)	Do not transfer on HFNC
(red hatched)	Unable to facilitate due to max flow on cylinders being 40l/min

Worked example: 10kg baby on High Flow of 20L/min in 60% oxygen

From Table 1: oxygen consumption = 9.2l/min

Based on the safety factor of 2 you will have only 1 E size cylinder to escort you from referring unit to ambulance and ambulance to destination unit.

E Cylinder contents (680l) ÷ oxygen consumption (9.2l/min) = 73 minutes

Based on these settings an E size cylinder will last a max of 73 minutes. However this does not build in the driving force of the cylinder required to run the ventilator, which requires the cylinder to be approx. ¼ full to give the driving force.

Table 2 has calculated the values based on flow rate and oxygen requirement to give the amount of time available based on this safety factor e.g. in this instance the cylinder will last approx. 55mins.

As a team you need to ensure that 55 minutes is enough time to complete the journey from bedside to ambulance and from ambulance to destination unit.

The second table you will need to then consider is table 3- the amount of aoxygen on board your ambulance- SJA carry 2x ZX cylinders. The length of time in minutes should cover your full journey. (The second cylinder will account for your safety factor). In this instance if the ambulance carried a ZX cylinder you would only have a max of 248 minutes for the journey. In general for our region this would be acceptable as most are within 90 minutes however you would need to consider further for children going out of region.