Pre-EDIT: protocol for a randomised feasibility trial of elastance-directed intrapleural catheter or talc pleurodesis (EDIT) in malignant pleural effusion

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ABSTRACT

Introduction Non-expansile lung (NEL) is a common cause of talc pleurodesis (TP) failure in malignant pleural effusion (MPE), but is often occult prior to drainage. Reliable detection of NEL would allow patients to be allocated between intrapleural catheter (IPC) and TP. High pleural elastance ($P_{el}$) has been associated with NEL in observational studies. Pre-EDIT is a randomised feasibility trial of elastance-directed IPC or TP (EDIT) management using a novel, purpose-built digital pleural manometer (Rocket Medical, UK).

Methods and analysis Consecutive patients with MPE without prior evidence of NEL or preference for IPC will be randomised 1:1 between EDIT management and standard care (an attempt at TP). The primary objective is to determine whether sufficient numbers of patients (defined as 30 within 12 months (or 15 over 6 months)) can be recruited and randomised to justify a subsequent phase III trial testing the efficacy of EDIT management. Secondary objectives include safety, technical feasibility and validation of study design elements, including the definition of $P_{el}$ using 4D pleural MRI before and after fluid aspiration. EDIT involves $P_{el}$ assessment during a large volume pleural fluid aspiration, followed by an attempt at TP or placement of an IPC within 24 hours. Patients will be allocated to IPC if the rolling average $P_{el}$ sustained over at least 250 mL fluid aspirated ($P_{el250}$) is $\geq$ 14.5 cm H$_2$O/L.

Ethics and dissemination Pre-EDIT was approved by the West of Scotland Regional Ethics Committee on 8 March 2017 (Ref: 17/WS/0042). Results will be presented at scientific meetings and published in peer-reviewed journals.

Trial registration number NCT03319186; Pre-results.

INTRODUCTION

Malignant pleural effusion (MPE) is a common clinical condition and frequently leads to disabling breathlessness. Survival in patients with MPE is notoriously heterogeneous and is determined primarily by tumour type. However, most patients survive for less than a year and in some, this may be limited to a few months.1 Efficient palliation of MPE symptoms is therefore a major priority for patients and their families. This is currently achieved either by admission to hospital for intercostal drain placement and an attempt at talc pleurodesis (TP) or outpatient placement of an indwelling pleural catheter (IPC).2 When successful, TP results in durable symptom control after a 4–7 day hospital stay, and obviates the need for intermittent, domiciliary drainage and the risk of ongoing complications including pleural infection. However, non-expansile lung (NEL) frequently complicates an attempt at TP and cannot be reliably predicted using baseline radiology or other parameters. Since an IPC will effectively palliate most MPEs, regardless of NEL,2 some centres advocate their use in all patients with MPE. However, an IPC is not acceptable to some patients. Anecdotally, this is particularly the case if immunosuppressive cancer therapy is planned, or their lifestyle or environment makes IPC management inconvenient or overly restrictive (eg, patients who enjoy swimming or reside in a warm climate).
Current guidelines direct clinicians to offer a choice between TP or IPC based on patient preference, given the equivalent efficacy of these approaches in two randomised controlled trials. However, this apparent equivalence cannot be generalised to patients with NEL, since the incidence of NEL was extremely low in these important studies, occurring in only 3/54 (6%) and 2/72 (3%) patients in TIME-2 and AMPLE, respectively. In clinical practice, the incidence of NEL is almost certainly higher; in audit data recently reported by our unit, NEL was identified in 15/65 patients with MPE (23%) who underwent complete pleural fluid drainage. In this series, NEL was also associated with a twofold to fourfold increase in all-cause mortality, which may explain the under-representation of NEL in the TIME-2 and AMPLE studies.

In our view, the ideal MPE treatment pathway would incorporate an initial functional assessment to determine the probability of underlying NEL, given the profound impact this has on the decision-making required by current guidelines (TP or IPC). Such a pathway, if accurate and efficient, would maximise patient choice in those with expansile lung (who could reasonably choose between TP and IPC) and minimise the rate of futile TP attempts in patients with NEL (avoiding the associated risks, cost and inconvenience). The current randomised feasibility pre-EDIT trial has been initiated to assess the feasibility and inform the design of a future randomised phase III trial testing the efficacy and informed choice of an abnormal P

Rationale for the pre-EDIT trial
Detection of NEL
Using routinely available clinical information NEL cannot be reliably detected prior to complete pleural drainage. A thick visceral peel encasing the lung may be seen on cross-sectional imaging in gross cases but is frequently absent. Following diagnostic or therapeutic pleural fluid aspiration, an ex-vacuo (hydro-) pneumothorax may be visible. However, this is also an insensitive sign, since a NEL may re-expand enough to appear expansile after removal of currently recommended volumes of fluid (<1.5 litres). Even after complete drainage of MPE, we have recently reported considerable interobserver variation in radiographic detection of NEL. Sonographic findings, including heavy septation or visceral pleural thickening, or abnormal M-mode and speckle-tracking end-points, have recently been reported as potential NEL biomarkers, but have yet to be validated in large cohorts. Development of a reliable predrainage biomarker for NEL is therefore urgently required.

Pleural elastance (P

The change in pleural cavity volume, which is assumed to be equal to the volume of fluid removed (\(\Delta V_{\text{OUT}}\)), is strongly associated with the presence of NEL and the occurrence of TP failure. However, previous studies have not attempted to allocate patients to TP or IPC using P

In previous observational studies, elevated P

This may occur early in the procedure where the aggregated compliance of the lung and parietal structures is compromised by technical limitations, largely relating to poor damping of pressure variations related to normal respiration and/or the need for cumbersome improvised equipment. In conjunction with Rocket Medical (UK), we have developed a novel, single-use, CE-marked digital pleural manometry (DPM) catheter which allows continuous IPP measurement during thoracentesis (see figure 1). IPP is measured once per second and is mechanically damped via the narrow independent lumen linking the pleural cavity to the electronic transducer (ET). IPP is also temporally damped by displaying a mean IPP on a re-usable digital display unit, based on the preceding 5 s of data. The precision and accuracy of the electronic transducer within the catheter has been laboratory tested by Rocket Medical (UK) during product development. Technical considerations in IPP measurement

Technical considerations in IPP measurement

Previous pleural manometry equipment has been hampered by technical limitations, largely relating to poor damping of pressure variations related to normal respiration and/or the need for cumbersome improvised equipment. In conjunction with Rocket Medical (UK), we have developed a novel, single-use, CE-marked digital pleural manometry (DPM) catheter which allows continuous IPP measurement during thoracentesis (see figure 1). IPP is measured once per second and is mechanically damped via the narrow independent lumen linking the pleural cavity to the electronic transducer (ET). IPP is also temporally damped by displaying a mean IPP on a re-usable digital display unit, based on the preceding 5 s of data. The precision and accuracy of the electronic transducer within the catheter has been laboratory tested by Rocket Medical (UK) during product development and found to read within ±5% of a calibrated laboratory device at simulated pressures between ±20 and ~30 cmH\(_2\)O. The manometer was EMC tested and passed BS EN 60601-1-2:2015 and BS EN 60601-1:2006+A1:2013.

EDIT pathway design
Monophasic vs biphasic NEL and selection of an abnormal P

Previous studies have reported characteristic patterns of IPP change in patients with NEL and expansile lung, during thoracentesis. Expansile lung is typically associated with a small linear reduction in IPP over the course of a large volume pleural aspiration. In contrast, NEL results in much larger fall in IPP, reflecting high P

Figure 1 Rocket Medical (UK) digital pleural manometer and re-usable display unit.
is severely limited resulting in a steep linear fall in IPP (monophasic NEL), typically in patients with gross visceral pleural thickening. In more subtle forms of NEL, IPP may initially behave similarly to expandable lung, as the pleural space partially conforms to the volume change and/or the lung expands as much as it can. However, this accommodation will eventually be overwhelmed as the lung reaches its maximum expansion, leading to a fall in IPP, but only after a considerable volume of fluid has been removed. This results in a biphasic $P_{EL}$ curve, which can only be detected if sufficient fluid is removed to reach the relevant inflection point. Importantly, TP success is likely to be reduced in patients with monophasic and biphasic NEL, and the EDIT pathway needs to be capable of detecting both.

In the only previous study that has linked $P_{EL}$ to TP success, Lan et al demonstrated that a $P_{EL}$ threshold of $\geq 19\text{cm H}_2\text{O/L}$ following aspiration of $500\text{mL}$ of pleural fluid was associated with a sensitivity for NEL of 79% (95% CI 0.49 to 0.99). However, the sensitivity of this approach is likely to have been limited by selection of a $P_{EL}$ threshold significantly above the upper limit of normal, which was subsequently defined as $14.5\text{cm H}_2\text{O/L}$ and the small aspiration volume used (500 mL), which is likely to have been inadequate to detect all cases of biphasic NEL. Adopting a lower $P_{EL}$ threshold and using a larger total aspiration volume may increase the sensitivity of NEL detection, but could potentially sacrifice specificity, particularly if IPP rises transiently due to coughing or unknown measurement artefacts.

Therefore, in the current pre-EDIT trial, we will use a novel definition of NEL, based on a rolling average of $P_{EL}$ recording over the preceding 250 mL fluid removed ($P_{EL,250}$), during a large volume pleural aspiration. The aspiration volume will only be limited by symptoms, a drop in IPP below previously reported safety thresholds or a target pleural effusion depth, based on repeated sonographic measurements (see Methods and analysis section for further detail). IPP pressures used to derive $P_{EL}$ will be consistently measured at end-expiration. NEL will be defined by a maximum $P_{EL,250} \geq 14.5\text{cm H}_2\text{O/L}$ (the previously reported upper limit of the normal range for $P_{EL}$) occurring at any point during large volume aspiration. This definition aims to detect NEL at the earliest possible opportunity, including in patients with biphasic NEL, while preserving specificity.

**Delivery of elastance-directed management and safety considerations**

By definition, the EDIT pathway requires an additional large volume thoracentesis prior to allocation to TP or IPC. If the allocated procedure cannot be delivered promptly, ideally on the same day, this offsets any pathway efficiency gained through detection of NEL. However, placement of any form of Seldinger drain may be technically challenging after removal of the majority of the effusion during $P_{EL}$ assessment. Therefore, within the EDIT protocol, thoracic ultrasound (TUS) images will be acquired regularly during aspiration, and the procedure terminated once a minimum safe depth of effusion has been reached (see Methods and analysis section for further details). The protocol also allows that, if required, a ‘Boutin-type’ needle can be used for pneumothorax induction to ensure safe placement of $P_{EL}$-allocated IPC or TP. This is regularly practised at level II thoracotomy centres, including our own, when no, or minimal, pleural fluid is present at local anaesthetic thoracotomy. However, if the current study finds that this is frequently required to deliver EDIT management, this may impact on the feasibility of subsequent multicentre phase III trial and any subsequent clinical deployment.

**Validation of the current definition of $P_{EL}$ using volumetric MRI**

$P_{EL}$ is currently defined as $\Delta IPP$ (cm H$_2$O)/$\Delta V_{OUT}$ (L), based on the assumption that $\Delta V_{OUT}$ is equivalent to the underlying change in pleural cavity volume. However, this assumption may not be valid, due to a combination of air and local anaesthetic introduced during the procedure, variable compliance of the surrounding structures and transient parenchymal-pleural fistulation. Moreover, since $\Delta IPP$ describes the aggregated behaviour of a potentially biphasic process, $P_{EL}$ values may inadequately describe pleural physiology in this setting. This uncertainty will be explored in the secondary objectives using volumetric pleural MRI, which allows precise measurement of intrathoracic structures.

If the current definition of $P_{EL}$ is validated using MRI, this may enhance the usability of the device used here. In the current protocol, $\Delta V_{OUT}$ needs to be manually recorded in parallel with IPP and the data integrated post-procedure. In the future, real-time integration of validated $\Delta V_{OUT}$ data with IPP data could facilitate real-time display of $P_{EL}$ (or $P_{EL,250}$), circumventing this time-consuming step. As exploratory objectives, volumetric MRI data will also be correlated with the development of symptoms during thoracentesis, the origin of which are poorly understood.

**Treatment preferences survey**

All potentially eligible (pre-screened) patients will be asked to complete a TPS (see online supplementary appendix 1). These qualitative data will be of value in deciding whether to pursue future studies of EDIT management and optimising the design of these.

**METHODS AND ANALYSIS**

**Study design and setting**

Pre-EDIT is a randomised feasibility trial. Thirty patients with symptomatic MPE will be recruited at a single centre: The Queen Elizabeth University Hospital, Glasgow, UK. Potentially eligible patients will also be identified and pre-screened at Glasgow Royal Infirmary. Patients will be randomised 1:1 to receive either pleural elastance-directed IPC or TP (‘EDIT management’), or standard care (placement of an intercostal drain and...
attempt at TP). A TPS will be offered to all potentially eligible (pre-screened) patients. The trial is sponsored by National Health Service (NHS) Greater Glasgow & Clyde and jointly funded by Rocket Medical (UK) and The West of Scotland Lung Cancer Research Group. The overall trial design is summarised in figure 2.

Sample size
As a feasibility study, this trial is not subject to a formal sample size estimation. Recruitment of 30 patients is likely to allow a reasonable view of the barriers which might be met in delivering EDIT management, to explore possible solutions, to document the time required to deliver the
Primary outcome measure will be recruitment rate. If recruitment is insufficient to make a meaningful comparison between the two arms, it will not be possible to recruit and randomise 30 patients over 12 months (or 15 patients in any 6-month period). The primary objective is to determine whether it is feasible to recruit and randomise 30 patients over 12 months (or 15 patients in any 6-month period). The primary outcome measure will be recruitment rate. Recruitment may be extended by up to five months if it becomes evident that the study is underpowered to detect a clinically relevant difference. In such circumstances, recruitment may be extended by an additional five months to allow the study to continue.

Since pre-EDIT involves novel equipment and imaging protocols, a review of data completeness and quality will be undertaken after completion of TUS assessment, DPM and MRI scanning in the first five patients randomised to EDIT management. This initial experience may be used to refine trial-specific instructions (TSIs) for use in subsequent patients. If significant data are missing or data are of such poor quality as to be uninterpretable from these patients, recruitment may be extended by up to five patients to replace these.

### Study objectives and outcome measures

#### Primary objective

The primary objective is to determine whether it is possible to recruit and randomise 30 patients over 12 months (or 15 patients in any 6-month period). The primary outcome measure will be recruitment rate.

#### Secondary and exploratory objectives

Secondary objectives and their associated outcome measures are summarised in [Table 1](#). Exploratory objectives are described in [Box 1](#).

#### Screening and eligibility assessment

Potentially eligible patients (defined as patients with symptomatic MPE) will be pre-screened by members of the parent clinical teams via cancer multidisciplinary team meetings, routine outpatient appointments and during inpatient reviews. Consecutive pre-screened patients meeting all inclusion criteria and without assessable exclusion criteria will be included in a pre-screening log, provided with a patient information sheet (PIS) at the earliest possible opportunity (see online supplementary appendix 2) and invited to a formal screening visit, during which all eligibility criteria will be assessed (see below). These patients will be given at least 24 hours between provision of the PIS and consent to consider participation.

#### Inclusion criteria

1. Clinically confident diagnosis of MPE, defined as any of the following:
   a. Pleural effusion with histocytologically proven pleural malignancy OR
   b. Pleural effusion in the context of histocytologically proven malignancy elsewhere, without a clear alternative cause for fluid OR

### Table 1: Secondary objectives and associated end points in the pre-EDIT study

<table>
<thead>
<tr>
<th>Secondary objectives</th>
<th>Secondary end points</th>
</tr>
</thead>
<tbody>
<tr>
<td>To determine the feasibility of ( P_{EL} ) computation using the novel DPM</td>
<td>The time taken to perform the EDIT large volume aspiration, including measurement of ( \Delta IPP ) using the DPM, recording of ( \Delta V ) and computation of ( P_{EL} ). The failure rate of the procedure, defined as the proportion of patients in whom ( P_{EL} ) cannot be computed</td>
</tr>
<tr>
<td>To determine the safety and tolerability of ( P_{EL} ) computation using the novel DPM</td>
<td>The occurrence of chest pain, cough or breathlessness during the procedure AEs and SAEs associated with use of the DPM</td>
</tr>
<tr>
<td>To assess the pleural fluid aspiration volume required to detect abnormal ( P_{EL} ) (where present)</td>
<td>The pleural fluid aspiration volume at which the rolling average pleural elastance over the preceding 250 mL (( P_{EL250} )) first exceeds the upper limit of normal (14.5 cm H( \text{2} )O/L)</td>
</tr>
<tr>
<td>To determine the proportion of patients allocated to EDIT management who require pneumothorax induction to facilitate safe ICD/IPC insertion following DPM</td>
<td>The proportion of patients in whom pneumothorax induction is required to facilitate safe ICD/IPC insertion in the EDIT arm</td>
</tr>
<tr>
<td>To test the assumption that pleural cavity ( \Delta V ) is equivalent to the volume of pleural fluid removed during aspiration</td>
<td>Pleural fluid aspiration volume (( \Delta V_{\text{inr}} )) Pleural cavity volume change, as measured directly using volumetric MRI (( \Delta V_{\text{MRI}} )), defined as pre-aspiration minus post-aspiration pleural cavity volume</td>
</tr>
<tr>
<td>To test the accuracy of a predictive model of pleural effusion volume (( V_{\text{TUS}} )) based on TUS measurements, which is a proposed inclusion criterion for the EDIT study</td>
<td>TUS estimated total pleural effusion volume (( V_{\text{TUS}} )) Pre-pleural fluid aspiration pleural cavity volume (( V_{\text{pre}} ))</td>
</tr>
</tbody>
</table>

AE, adverse events; DPM, digital pleural manometer; EDIT, elastance-direct intrapleural catheter or talc pleurodesis; ICD, intercostal drain; IPC, indwelling pleural catheter; IPP, intrapleural pressure; \( P_{EL} \), pleural elastance; SAE, serious adverse event; TUS, thoracic ultrasound; \( V \), pleural fluid volume.

To explore anatomical changes using MRI that may account for the development of symptoms such as chest pain or cough during large volume thoracentesis.

To explore the factors important to patients with symptomatic malignant pleural effusion when deciding upon first-line definitive pleural intervention.

To develop a novel predictive model for pleural effusion volume estimation applicable to a wide range of effusion volumes using uniplanar TUS measurement.

To evaluate the feasibility and potential utility of M-mode assessment of cardiac impulse lung displacement in patients undergoing EDIT management.

To investigate potential novel MRI biomarkers, such as visceral pleural thickness and parenchymal volume change and strain during respiratory cycle pre-DPM, which may predict NEL.

DPM, digital pleural manometer; EDIT, elastance-direct intrapleural management.

To develop a novel predictive model for pleural effusion volume estimation applicable to a wide range of effusion volumes using uniplanar TUS measurement.

To evaluate the feasibility and potential utility of M-mode assessment of cardiac impulse lung displacement in patients undergoing EDIT management.

To investigate potential novel MRI biomarkers, such as visceral pleural thickness and parenchymal volume change and strain during respiratory cycle pre-DPM, which may predict NEL.

DPM, digital pleural manometer; EDIT, elastance-direct intrapleural management.

Pleural effusion with typical features of malignancy with pleural involvement on cross-sectional imaging.

Degree of breathlessness for which therapeutic pleural intervention would be offered.

Age > 18 years.

Expected survival > 3 months.

Written informed consent.

Exclusion criteria

1. Women who are pregnant or lactating.
2. Clinical suspicion of NEL for which TP would not be offered.
4. Previous ipsilateral failed TP.
5. Estimated pleural fluid volume ≤ 1 L (defined by TUS).
6. Any contraindication to ICD or IPC insertion, including:
   a. Irreversible coagulopathy.
   b. Inaccessible pleural collection, including lack of suitable IPC tunnel site.
7. Any contraindication to MRI scanning, including:
   a. Claustrophobia.
   b. Cardiac pacemaker.
   c. Ferrous metal implants or retained ferrous metal foreign body.
   d. Previously documented reaction to Gadolinium-containing intravenous contrast agent.
   e. Significant renal impairment (estimated glomerular filtration rate < 30 mL/min).

Informed consent

Consent will be a two-step process. Pre-screened patients, potentially agreeable to trial involvement will be invited to a formal screening visit, during which a member of the research team will discuss the trial and seek written consent to formal screening (see online supplementary appendix 2). This will involve formal assessment of all eligibility criteria, including a bedside TUS for measurement of pleural effusion volume ($V_{TUS}$). Patients attending a screening visit will be added to a screening log. Patients meeting all eligibility criteria will be asked to give written consent to trial enrolment and randomisation.

Treatment preferences survey

All pre-screened patients will be eligible and asked to participate in the TPS, irrespective of whether they meet all eligibility criteria and/or wish to participate in the main trial. Pre-screened patients will be provided with a separate TPS PIS (see online supplementary appendix 3) and will be given sufficient time, based on their own judgement, to consider participation before signing a separate consent form for involvement in the TPS (see online supplementary appendix 3).

Trial interventions

The trial interventions are summarised in figure 2 and described in detail below. Further information, in the form of TSIs for all interventions are available in online supplementary appendices 4–9.

Baseline assessments

Following consent, elective hospital admission and baseline assessment will be completed by a member of the trial team. The following data will be recorded prior to randomisation:

1. Patient demographics and physical characteristics.
2. Mode of presentation, current diagnosis and smoking history.
3. Eastern Cooperative Oncology Group performance status.
4. Medical history and current medication.
5. Previous pleural interventions.
6. Symptoms, including pain and breathlessness according to 100 mm visual assessment (VA) scores.
7. Results of routine haematological and biochemical tests (within 10 days).
8. Baseline TUS findings.

Randomisation

Immediately after baseline assessment, patients will be randomised 1:1 and allocated using random permuted blocks to either EDIT management or standard care. A validated online system will be used (www.sealedenvelope.com). The availability of potential minimisation factors for the subsequent phase III EDIT trial will be recorded but not used in randomisation, including the LENT prognostic score. The allocated management strategy will commence within 72 hours of randomisation.

Standard care

Following procedure-specific written consent, a 12Fr intercostal drain will be placed to facilitate passive fluid drainage at a rate not exceeding 1000 mL/hour. Chest ultrasounds.
radiographs (CXRs) will be performed post-ICD inser-
tion and repeated every 18–24 hours following insertion.
Four grams of sterile talc will be administered as a slurry,
if there is no evidence of NEL or significant residual
pleural fluid, as per existing guidelines. The intercostal
drain will be removed once fluid output falls below
250 mL in the preceding 24-hour period, in the presence
of a patent drain.

Where NEL or residual fluid is identified, drain
patency will be assessed by flushing. Thoracic suction
may be applied at the discretion of the primary physi-
cian. An additional CXR will be repeated after a further
18–24 hour period. Talc slurry will be administered once
at least 50% re-apposition of the visceral and parietal
pleural is achieved, based on visual CXR estimation, as
per existing guidelines. If this is not achieved within
48 hours of drain placement, further management will be
at the discretion of the primary physician. Further details
are given in online supplementary appendix 4.

EDIT management
MRI scanning prior to large volume pleural fluid aspiration and PEL assessment
Patients will be scanned using a 3.0T Siemens Prisma
MRI scanner. The affected thoracic cavity will be local-
ised and an isotropic T1-weighted volume acquired
using volumetric interpolated breath-hold examination
(VIBE) sequences. A stack of axial slices covering the
entire lung and surrounding pleura will be acquired as a
set of short breath-holds. Time-resolved 3D MR imaging
of the complete thorax will then be obtained during
tidal free-breathing and maximal inspiratory/expira-
tory efforts. A modified time-resolved angiography with
interleaved stochastic trajectories (TWIST) sequence
will be used for this purpose. Following this, Gd-DTPA
contrast (Gadovist) will be administered as a 15–40 mL
bolus (0.05 mmol/kg). VIBE sequences will be reac-
tained at copied slice positions to provide comparative
postcontrast images at multiple time points. Further
scanning details are given in online supplementary
appendix 5.

Thoracic ultrasound
Following MRI scanning, a TUS scan will be performed.
This will allow the operator to identify a safe site for inser-
tion of the digital pleural manometry catheter, where
possible, in the posterior axillary line in the second rib
space above the costophrenic angle. Deviation from this
site will be recorded. For assessment of the secondary
objectives, measurement of the lateral, posterior and
median subpulmonic effusion heights in centimetres
(LH, PH and SH) will be performed with the patient
sitting upright at 90°. The total pleural effusion volume
(in millilitres) will be estimated using the Goekcke formula
(VTUS = (LH + SH) x 70). For examination of the explor-
atory objectives (see box 1), M-mode measurements of
the apleural lacerate lobe will also be acquired, during a
breath hold at end-expiration.

Large volume pleural fluid aspiration and computation of PEL
After infiltration of the insertion site with local anaes-
thetic, the digital pleural aspiration catheter will be
inserted at the site marked using TUS. Pleural fluid will
be removed in 50 mL aliquots until any of the following
occur:

► The patient develops chest discomfort or excessive
coughing.
► An intrapleural pressure of \( \leq -20 \text{ cmH}_2\text{O} \) is reached.
► The target maximum aspiration volume is reached
(horizontal costal to visceral pleural distance \( \leq 30 \text{ mm} \)).

Sequential end expiratory IPP measurements will be
recorded after each 50 mL aliquot. Additionally, the
highest and lowest IPP values recorded during maximal
respiratory manoeuvres at 200, 500 and 1000 mL will be
recorded. Postprocedure, \( P_{\text{EL250}} \) values will be calculated
summarising \( P_{\text{EL}} \) over the preceding 250 mL of fluid
removed. The first \( P_{\text{EL250}} \) value will therefore be computed
based on the IPP change between 0 and 250 mL divided
by 0.25. Equivalent \( P_{\text{EL250}} \) values will then be computed
after each subsequent 50 mL fluid removed. Thus, after
300 mL has been removed, the next \( P_{\text{EL250}} \) value will be
computed using the IPP change between 50 and 300 mL,
again divided by 0.25. The highest recorded \( P_{\text{EL250}} \) in each
case (MaxPEL250) and total pleural fluid volume removed
will be recorded. Further details are given in online
supplementary appendix 6.

MRI scanning after large volume pleural fluid aspiration and PEL assessment
Following DPM, a further thoracic MRI scan will be
performed. Identical T1-weighted VIBE and TWIST
sequences will be acquired; however, further intravenous
contrast will not be administered.

Allocation and delivery of PEL-directed management
Participants will be allocated to IPC or an ICD and
attempt at TP based on their highest recorded \( P_{\text{EL250}} \)
in each case (MaxPEL250), as follows:

\[
\text{Max} P_{\text{EL250}} \begin{cases} \geq 14.5\text{ cm H}_2\text{O/L} & \text{allocated to IPC} \\ < 14.5\text{ cm H}_2\text{O/L} & \text{allocated to ICD and an attempt at TP} \end{cases}
\]

Both will be performed using standard Seldinger techniques based on repeat TUS assess-
ment, unless there is insufficient residual fluid left for
this purpose (in the judgement of the operator). In this
situation, a ‘Boutin-type’ needle may be used to obtain
blunt access to the pleural cavity and create an istro-
genic (hydro-) pneumothorax for the purpose of safe
drain insertion. The remainder of the ICD/IPC inser-
tion will then proceed in the usual fashion. A CXR will
be performed postprocedure to assess the drain posi-
tion. Further detail is provided in online supplementary
appendices 7–9.
Management following $P_{EL}$-directed IPC or intercostal drain insertion

Patients allocated to IPC placement will be managed using standard local policies, as detailed in the TSI (see online supplementary appendix 9). For patients allocated to intercostal drain insertion and TP, postinsertion management will be identical to patients receiving standard care.

Data collection and study visits

VA scores

VA scores for chest pain and breathlessness will be documented at baseline and then daily for 7 days following ICD or IPC placement. Following this, VA scores will be performed weekly until the 28-day clinical follow-up appointment.

Study follow-up visits

Routine clinical appointments are planned for all patients at approximately 7, 28, 60 and 90 days after discharge. A single-study-specific follow-up visit at 90 days ($\pm 10$) will coincide with routine follow-up where possible. At this visit, a CXR will be acquired and details of hospital admissions, repeat pleural interventions, clinic visits and survival status shall be recorded based on clinical history, augmented by electronic records systems. Where patients are unfit or unable to attend clinic, or have died, these data shall be recorded using electronic systems.

Further pleural intervention

In the event of hospital readmission, further pleural procedures will not be restricted by study participation. Where a gradual return of breathlessness is encountered during follow-up, the research team will assess the likely cause. IPC complications such as infection or blockage will be managed at the discretion of the primary physician. If recurrent MPE is identified following TP and occupies greater than an estimated one-third of the hemithorax on CXR, IPC insertion or therapeutic pleural aspiration will be offered if clinically appropriate. Intervention for smaller volume MPE recurrence will be offered where treatment consensus is achieved with a second respiratory physician blinded to trial group allocation. In the event of disagreement, a third (blinded) casting opinion will be sought.

Data management

Study data will be recorded on paper case report forms and securely transferred to the Queen Elizabeth University Hospital Clinical Research Facility and entered into a trial database. All CXR, CT and MRI images relating to trial participation will be securely stored on NHS systems in line with routine clinical practice. Representative TUS images and M-mode cine clips will be stored on an encrypted trial hard drive.

Statistical analysis plan

The primary objective of trial recruitment will be expressed as a mean monthly rate over the complete trial period and over each 6-month period during which the trial is open. The time taken to perform digital pleural manometry, its failure rate, the incidence of adverse events (AEs) and serious adverse events (SAEs) associated with EDIT management, the number of patients requiring a Boutin needle for ICD/IPC insertion and aspiration volume required to detect abnormal $P_{EL}$ will be reported by simple descriptive statistics or proportions where appropriate. Differences in mean/median values will be assessed using Students t-test or Wilcoxon rank test. Pearson $\chi^2$ test and exact 95% CIs will be used to compare proportions. A standard significance level of 0.05 will be used. The Bland-Altman method will be used to assess agreement between $\Delta V_{OUT}$ and $\Delta V_{MRI}$ measurements and between preaspiration $V_{TUS}$ and $V_{MRI}$ measurements.

End of trial

Trial recruitment commenced on 28 August 2017 and will terminate on 28 August 2018 or after 30 patients have been recruited, whichever is soonest. Trial participation will cease once the final patient has completed their 90-day follow-up.

Changes to the study protocol since trial opening

The protocol described accurately reflects V.2.5 of the protocol, dated 15 December 2017. The protocol history is summarised below:

V.2.0, dated 4 March 2017

At request of REC, recruitment process modified such that follow-up contact to invite for screening visit to be made by clinical nurse specialist rather than research team.

V.2.1, dated 5 April 2017

References to ‘Boutin needle’ changed to ‘Boutin-type needle’.

Randomisation process changed from minimisation using LENT score to simple random 1:1 allocation with recording of availability of LENT score to assess feasibility of minimisation by LENT in future EDIT trial.

V.2.2, dated 11 May 2017

Introduction of 5-patient ‘run-in’ period to allow refinement of TUS, DPM and MRI protocols and assessment of data completeness.

Removal of statement committing to guidewire placement down Boutin-type needle (where used).

Removal of statement committing to pneumothorax induction in endoscopy suite.

V.2.3, dated 4 August 2017

Extension of time allowed between randomisation and delivery of intervention from immediate to up to 72 hours.

V.2.4, dated 9 October 2017

References to ‘Boutin needle’ changed to ‘Boutin-type needle’.
► Remove preprocedure TUS-estimated target volume as stop criterion for DPM and replace this with target horizontal costal-visceral pleural distance on TUS assessment at intervals during the aspiration procedure.
► Removal of 2-week follow-up appointment.
► Follow-up interval to start from date of discharge rather than date of procedure.
V.2.5, dated 15 December 2017
► Recording of pre-screened patients.
► Introduction of TPS.

ETHICS AND DISSEMINATION

Safety reporting
Details of any AEs or SAEs will be collected during routine and trial follow-up visits. All AEs and SAEs will be recorded in the patient’s medical records and reported to the trial sponsor.

Dissemination
Pre-EDIT, and the ultimate intention to definitively evaluate EDIT management if found to feasible, will be publicised at regional and national meetings. The results of pre-EDIT trial will be presented at scientific meetings and published in peer-reviewed journals.

Trial management
A Trial Management Group consisting of the chief investigator, clinical research fellow, lead trial research nurse, statistician and administrative assistant will oversee the running of the trial and meet on a monthly basis.

Contributors
GAM: contribution to the conception and design of the work, data acquisition, analysis and interpretation of data for the work; drafting the work. GAM, ST, ACK, JEF, PM, AC, KGB: final approval of the version to be published; agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. ST: contribution to the conception and design of the work and interpretation of data for the work. ST, ACK, JEF, PM, AC, KGB: revising the work critically for important intellectual content; final approval of the version to be published. ACK: contribution to the design of the work and data acquisition, analysis, and interpretation of data for the work. PM: contribution to the design of the work, analysis and interpretation of data for the work. AC: contribution to the design of the work. KGB: principal contribution to the conception and design of the work; data acquisition, analysis and interpretation of data for the work

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Competing interests
Rocket Medical (UK) have part-funded this work and will supply the digital pleural manometry equipment to be used in the study.

Patient consent
Not required.

Ethics approval
Pre-EDIT was approved by the West of Scotland Regional Ethics Committee on 8 March 2017 (Ref: 17/WS/0042).

Provenance and peer review
Not commissioned; externally peer reviewed.

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REFERENCES